

Fishery Data Series No. 94-23

Abundance and Composition of the Northern Pike Populations in Volkmar, T, East Twin and Harding Lakes, 1993

by

Gary A. Pearce

September 1994

Alaska Department of Fish and Game

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TABLE OF CONTENTS

	<u>Page</u>
LIST OF FIGURES	iii
LIST OF APPENDICES	iv
ABSTRACT	1
INTRODUCTION	2
Background	2
Study Area Descriptions	2
Volkmar Lake	2
T Lake	4
East Twin Lake	5
Harding Lake	6
Study Goals and Objectives	6
METHODS	7
Study Design	7
Data Collection	12
Data Analysis	13
Abundance Estimation	13
Composition Estimation	17
RESULTS AND DISCUSSION	18
Volkmar Lake	18
Abundance Estimation	18
Composition Estimation	18
T Lake	21
Abundance Estimation	21
Composition Estimation	21

TABLE OF CONTENTS (Continued)

	<u>Page</u>
East Twin Lake	23
Abundance Estimation	23
Composition Estimation	24
Harding Lake	26
Abundance Estimation	26
Composition Estimation	28
ACKNOWLEDGEMENTS	28
LITERATURE CITED	29
APPENDIX A	35
APPENDIX B	38
APPENDIX C	42
APPENDIX D	45
APPENDIX E	48
APPENDIX F	50
APPENDIX G	52
APPENDIX H	56
APPENDIX I	60
APPENDIX J	63
APPENDIX K	66
APPENDIX L	71
APPENDIX M	74
APPENDIX N	77
APPENDIX O	79
APPENDIX P	81
APPENDIX Q	84

LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
1. Tanana River study areas	3
2. Volkmar Lake study area	8
3. T Lake study area	9
4. East Twin Lake study area	10
5. Harding Lake study area	11
6. Daily cumulative length distribution frequencies of northern pike captured in Volkmar Lake, 1993	20
7. Daily cumulative length distribution frequencies of northern pike captured in T Lake, 1993	22
8. Daily cumulative length distribution frequencies of northern pike captured in East Twin Lake, 1993	25
9. Daily cumulative length distribution frequencies of northern pike captured in Harding Lake, 1993	27

LIST OF APPENDICES

<u>Appendix</u>	<u>Page</u>
A. Recreational fishing effort, harvest, and exploitation of northern pike in Volkmar, T, East Twin, and Harding lakes, 1977-1993	36
B. Sampling dates and abundance estimate types for Volkmar, T, East Twin, and Harding lakes.	39
C. Finclips and tags assigned to northern pike in Volkmar T, East Twin, and Harding lakes, by year	43
D. Number of northern pike marked and recaptured by event in Volkmar, T, East Twin, and Harding lakes, 1993	46
E. Abundance and density of various size groups of northern pike (> 299 mm FL) in Volkmar, T, East Twin and Harding lakes, by year	49
F. Model selection criteria used by program CAPTURE, for Volkmar, T, and East Twin lakes, 1993	51
G. Percent RSDs and abundance of northern pike > 299 mm FL in Volkmar, T, East Twin, and Harding lakes, by year	53
H. Length frequencies of all northern pike sampled in Volkmar Lake, 1985-1993	57
I. Estimated age composition and cohort abundance of the northern pike population (>299 mm FL) in Volkmar Lake, 1985-1993	61
J. Estimated length-at-age of northern pike (>299 mm FL) in Volkmar Lake, 1985-1993	64
K. Length frequencies of all northern pike sampled in T Lake, 1986-1993	67
L. Estimated age composition and cohort abundance of the northern pike population (>299mm FL) in T Lake 1986-1993	72
M. Estimated length-at-age of northern pike (>299 mm FL) in T Lake 1986-1993	75
N. Estimated age composition and cohort abundance of the northern pike population (>299 mm FL) in East Twin Lake, 1992-1993	78

LIST OF APPENDICES (Continued)

<u>Appendix</u>	<u>Page</u>
O. Estimated length-at-age of northern pike (>299 mm FL) sampled in East Twin Lake, 1992-1993	80
P. Length frequency of all northern pike sampled in East Twin Lake, 1993	82
Q. Estimated proportion of the population, cohort abundance, and mean length by age class for northern pike in Harding Lake, 1990-1993	85

ABSTRACT

Populations of northern pike *Esox lucius* in Volkmar, T, East Twin, and Harding lakes in interior Alaska were studied during spawning in the spring of 1993. Multiple capture-recapture events were used to estimate the abundance of northern pike > 299 millimeters fork length. Abundance was estimated to have been 4,160 northern pike in Volkmar Lake in 1993 (SE = 605; 15.2 per hectare). The abundance of northern pike in T Lake in 1993 was estimated to have been 853 fish (SE = 137; 5.4 fish per hectare). The estimated abundance of northern pike in East Twin Lake was 6,070 fish (SE = 757; 11.5 fish per hectare). Abundance of northern pike in Harding Lake in 1993 was estimated at 9,309 fish (SE = 750; 5.1 fish per hectare). Populations of northern pike in Volkmar, East Twin, and Harding lakes were composed primarily of the Relative Stock Density category of stock-sized fish (300-524 millimeters), while quality-sized fish (525-654 millimeters) predominated in the population in T Lake. Age 5 northern pike were most abundant in all lakes except Harding Lake, where age 4 fish were dominant. Data collected since the inception of northern pike research in Volkmar, T, East Twin, and Harding lakes are summarized.

KEY WORDS: Northern pike, *Esox lucius*, Volkmar Lake, T Lake, East Twin Lake, Harding Lake, abundance, mark-recapture, length/age composition.

INTRODUCTION

Background

Northern pike *Esox lucius* are popular with sport anglers in Alaska. An estimated 100,642 northern pike were caught statewide during 1992, of which 18,616 (18%) were harvested (kept) according to Mills (1993). Excluding anadromous and saltwater species, northern pike ranked third in preference (following rainbow trout *Oncorhynchus mykiss* and Arctic grayling *Thymallus arcticus*) of freshwater fish both caught and harvested statewide during 1992. In the Arctic-Yukon-Kuskokwim region (AYK), where the highest percentage (61%; 11,302) of the statewide harvest of northern pike occurred, northern pike ranked fourth among all species harvested in recreational fisheries, and second for those non-anadromous species considered indigenous to the region. Harvests of northern pike in the AYK region have averaged about 15,103 fish between 1977 and 1992, with a harvest range from 11,302 to 20,771.

Within AYK, harvest of northern pike from waters of the Tanana River drainage comprised 54% (6,148 fish) of the regional total for the species during 1992. East Twin, George, Harding, and Volkmar lakes, in that order, were the sites of the most popular fisheries for northern pike in lakes in the Tanana River drainage during 1992, accounting for 27% (1,647 fish) of the total harvest.

Cursory stock assessment and creel surveys of northern pike in the Tanana River drainage were conducted from 1968 to 1984 (Alt 1969; Cheney 1972; Hallberg 1984; Peckham 1972-1985). Research initiated at Volkmar Lake in 1985 (Peckham 1986) provided the first estimate of northern pike abundance. Research conducted from 1986 through 1993 has provided additional estimates of abundance, along with information on catch-per-unit of sampling effort (CPUE), catchability, sampling methods, life history, age, sex, and size composition and estimates of sustainable yield of northern pike in George, Volkmar, T, and Harding lakes (Peckham and Bernard 1987; Clark et al. 1988; Clark 1988; Clark and Gregory 1988; Timmons and Pearse 1989; Burkholder 1991, 1992; Pearse 1990, 1991; Hallberg and Bingham 1992; Pearse and Hansen 1992, 1993; Pearse and Burkholder 1993; Pearse and Clark 1992; Roach 1993; Skaugstad and Burkholder 1992). This report documents research conducted in 1993 concerning the abundance, and composition of the populations of northern pike in Volkmar, T, East Twin, and Harding lakes.

Study Area Descriptions

Volkmar Lake:

Volkmar Lake (64°07'N, 145°11'W) is a remote 273 ha (675 ac) lake located approximately 25 km northeast of the town of Delta Junction (Figure 1). The lake is accessible during the open water season by float-equipped aircraft. Snow machines and ski-equipped aircraft provide access during the winter. Volkmar Lake lies at an elevation of 326 m and has a maximum depth of 12.8 m. The lake has two small inlets and an ill-defined outlet that drains westerly through wetlands toward the Goodpaster River. Near shore waters are shallow with beds of aquatic vegetation providing spawning and rearing substrate for

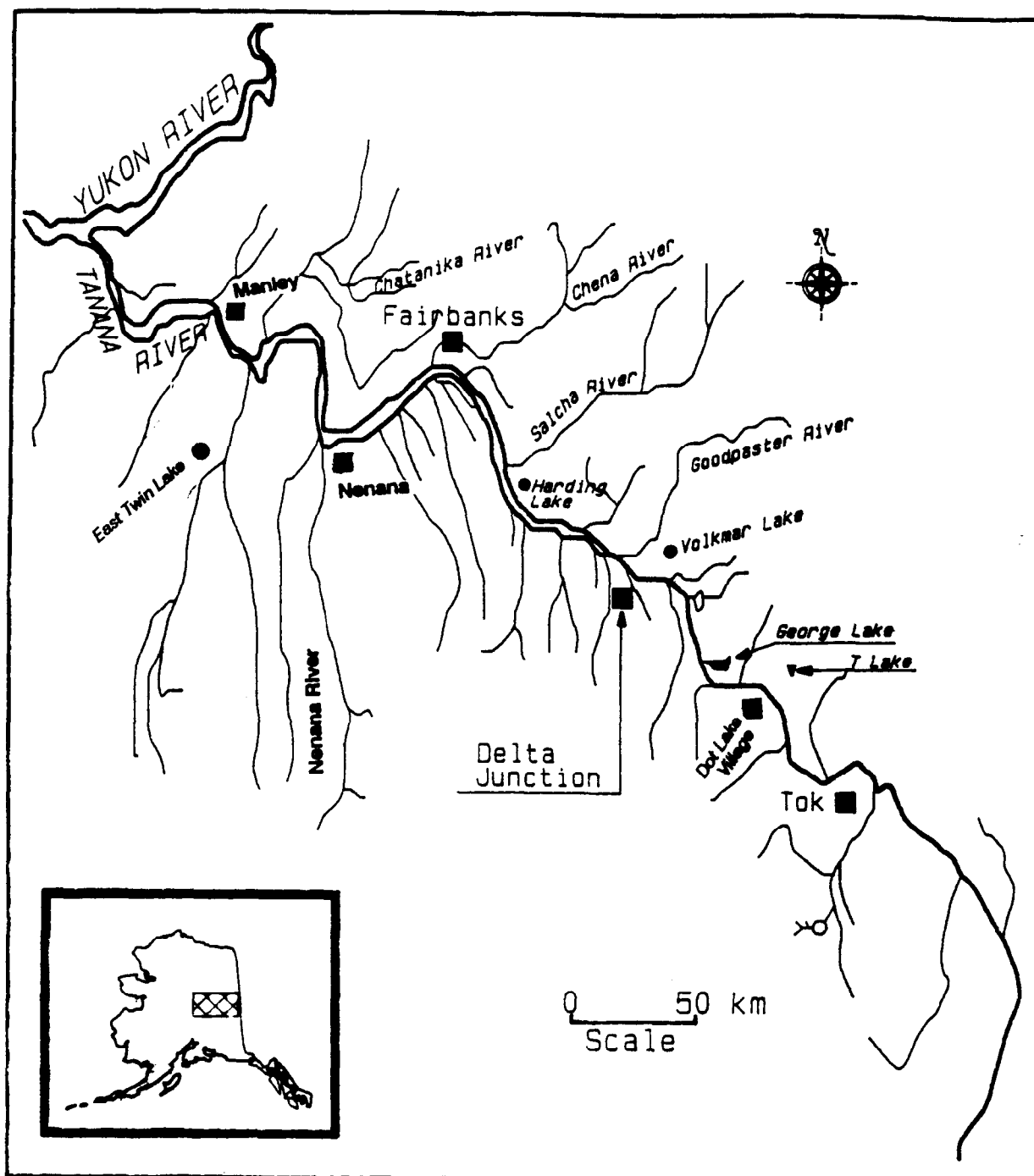


Figure 1. Tanana River study areas.

northern pike. Volkmar Lake is typically ice-free from mid-May to early October, and spawning activity of northern pike generally coincides with the beginning of the ice-free period and continues for up to two weeks, into early June. Other fish species present include humpback whitefish *Coregonus pidschian*, least cisco *Coregonus sardinella*, and slimy sculpin *Cottus cognatus*.

The popularity of Volkmar Lake as a recreational area continues to grow due to land disposals around the lake by the State, improved winter access from new snow machine trails and roads in the Delta Junction Agricultural Project, and increased summer and winter use by cabin owners around the lake and on the nearby Goodpaster River. For the period 1981 through 1992, estimated annual fishing effort averaged 494 angler days (range 129 to 1,052; Mills 1993; Appendix A) and an estimated average fishing pressure of 1.8 ad/ha. The estimated harvest for northern pike averaged 415, ranging from 84 (1990) to a high of 777 (1982), with an average harvest of 0.8 northern pike per angler-day. In 1992, 18% of the catch was harvested. The average annual harvest per hectare is 1.5 northern pike. In 1992, of 1,182 northern pike under 30 inches total length (TL, 720 mm fork length [FL]) caught in Volkmar Lake, 158 (13%) were retained (Mills 1993). Almost all northern pike over 30 inches caught were kept (73 of 74). The component 30 inches and longer comprised 6% of the total catch (74 of 1,256), and 32% of the harvest (73 of 231). Recreational fishing occurs year-round.

The research program on northern pike in Volkmar Lake began in 1985, with initial efforts focused on obtaining an abundance estimate. In 1986, several gear types and deployment techniques were evaluated to identify a non-lethal, efficient sampling method for the capture of northern pike. Seines proved to be the most effective capture gear of those evaluated (gill nets, various trap and fyke nets, and seines) for study of this northern pike population (Peckham and Bernard 1987). Results of subsequent investigations have been reported upon by Clark and Gregory (1988); Timmons and Pearse (1989); Pearse (1990, 1991); Pearse and Clark (1992); Pearse and Burkholder (1993); and, Pearse and Hansen (1993).

T Lake:

T Lake (63°48'N, 143°53'W) is a remote fly-in lake located approximately 18 km north of Dot Lake village along the Alaska Highway (Figure 1). The 158 ha (390 ac) lake lies at an elevation of 434 m and has a maximum depth of 17 m. The lake has two small inlets and an intermittent outlet that flows from the northeast corner into Billy Creek, a tributary of the Tanana River to the south. Near-shore waters are shallow with beds of aquatic vegetation providing spawning and rearing substrate for northern pike. T Lake is typically ice-free from mid-May to early October, and spawning of northern pike generally coincides with the beginning of the ice-free period and continues for up to two weeks, into late May. Other fish species in the lake include burbot, humpback whitefish, and least cisco.

Fishing pressure is believed to be low, but exploitation rates are high, compared with other area waters (Appendix A). Stock assessment studies have been conducted annually since 1986 (Peckham and Bernard 1987; Clark 1988; Timmons and Pearse 1989; Pearse 1990, 1991; Pearse and Burkholder 1993; and, Pearse and Hansen 1993).

East Twin Lake:

East Twin Lake (63° 26'N, 150° 39'W) is a remote fly-in lake located approximately 139 km southwest of Fairbanks (Figure 1). The 526 ha lake lies at an elevation of 211 m, has a maximum depth of 13.7 m, and a shoreline circumference of 7.9 km. The lake has three small inlets and an outlet that possibly flows during flood events from the north shore into the Kantishna River to the east. Nearshore waters are shallow with beds of aquatic vegetation providing spawning and rearing substrate for northern pike. East Twin Lake is typically ice-free from mid-May to mid-October, and spawning of northern pike is believed to coincide with the beginning of the near-shore ice-free period and continues for up to two weeks into late-May. Other fish species in the lake include humpback whitefish, and least cisco.

East Twin Lake has supported a fly-in fishery for northern pike for many years, with anecdotal reports of good success in catching large fish dating back over 30 years. The sport fishery has been characterized by both winter and summer harvests, and by limited exploitation from commercial sport fishing guides (Bill Lambert, Guide, pers comm.). The current level of subsistence harvest is undocumented, but is believed to be minimal. Over the years, numerous trophy fish certificates (for fish over 15 lbs or 6.8 kg) have been issued for northern pike harvested in this lake. The size and age composition of the harvest is undocumented. For the period 1983 through 1992, estimated annual fishing effort averaged 512 angler-days (range 76 to 1,035; Mills 1993), as described in Appendix A. This is equivalent to an estimated annual fishing pressure of 1.0 angler days per ha. For the same period, the estimated harvest averaged 425 northern pike, ranging from zero in 1985 (likely an underestimate) to a high of 839 northern pike in 1983, with a success of 0.8 northern pike per angler-day kept. In 1992, of 2,589 northern pike under 30 inches total length (TL, 720 mm fork length [FL]) caught in East Twin Lake, 461 (18%) were retained (Mills 1993). About 10% of the northern pike over 30 inches caught were kept (85 of 819). The component of the recreational harvest 30 inches and longer comprised 24% of the total catch (74 of 1,256), and 18% of the harvest (85 of 461). Recreational fishing occurs year-round.

Stock assessment of the northern pike population in East Twin Lake was initiated during the 1992 field season (Pearse and Burkholder 1993). Previous investigations have been limited, and reflect brief sampling to collect age and growth data relative to the fish species present, and limnological parameters (Alt 1969; Cheney 1972; and, Hallberg 1984).

Harding Lake:

Harding Lake (64°25'N, 146°50'W) is located 54 km (69 km by road) southeast of Fairbanks (Figure 1). The lake can be reached by three roads that exit the Richardson Highway. The surface elevation is 217 m, surface area is 1,000 ha, and maximum depth is 43 m. In addition to runoff, the lake is fed by springs, permafrost seeps, and two inlets; there is no outlet. The littoral zone comprises 33% of the surface area. The lake supports several indigenous species including northern pike, burbot, least cisco, lake chub *Couesius plumbeus*, and slimy sculpin. Fish species introduced in support of an ongoing program to increase recreational utilization of the water body include lake trout *Salvelinus namaycush*, coho salmon *Oncorhynchus kisutch*, sockeye salmon *Oncorhynchus nerka*, rainbow trout, inconnu *Stenodus leucichthys*, Arctic char *Salvelinus alpinus*, and Arctic grayling.

From 1983 to 1992, the estimated annual fishing effort ranged from 708 to 5,155 ad, and averaged 3,276 (Mills 1993; Appendix A). This equates to an estimated average fishing pressure of 3.3 ad/ha. The estimated harvest averaged 1,068 northern pike, ranging from 178 (1983) to 2,092 (1988) fish, with an average success of 0.3 northern pike per angler-day kept. In 1992, of 2,976 northern pike under 30 inches total length (TL, 720 mm fork length [FL]) caught in Harding Lake, 241 (8%) were retained (Mills 1993). About 24% of the northern pike over 30 inches caught were kept (100 of 424). The component of the recreational harvest 30 inches and longer comprised 12% of the total catch (424 of 3,400), and 29% of the harvest (100 of 341). The first major stock assessment of northern pike in Harding Lake occurred in 1990 (Burkholder 1991) with abundance and length and age compositions estimated annually through the summer of 1993 (Skaugstad and Burkholder 1992). In addition, Roach (1993) presents data relative to movements and distribution of northern pike determined through radio-telemetry.

Study Goals and Objectives

The long-term goal of the northern pike research program is to accurately and precisely describe the stock status of selected northern pike populations on a regular basis, and to use the data to estimate sustainable yield. The specific objectives for 1993, Project: F-10-9, Job R-3-4 (c) are to estimate the population abundance, size, and age composition of northern pike in Volkmar, T, East Twin, and Harding lakes.

This report presents historic estimates of abundance by size-class, density, length and age composition, and harvest of the northern pike populations in these waters. Note that during 1992, the collection of age-related data was limited to all fish sampled in East Twin Lake, and only recaptured northern pike tagged in prior years in the remaining waterbodies. See Pearse and Hansen (1993) for analyses and discussion of error in age assessment.

METHODS

Study Design

Population sampling and multiple capture-recapture experiments for closed populations of northern pike were conducted in the four study lakes (Volkmar, T, East Twin, and Harding) from late May to early June during 1993. Prior experience indicated that population studies of northern pike in interior Alaskan lakes are best conducted during and immediately after the spawning period, which coincides with spring ice melt during mid to late May. Northern pike concentrate and move in near-shore waters at this time to spawn and later feed making them more available to the sampling gear. Low water temperatures minimize temperature-sensitive handling injuries (Peckham and Bernard 1987; Clark 1988; and, Pearse and Clark 1992). Daily peaks in activity, as reflected by both observation of fish activity and catch of ripe or feeding fish in gill nets and seines, normally occurs during mid-day, generally between 1000 and 2000 hours. Sampling efforts were therefore focused to include this peak period of daily near-shore activity (within 100 m of the shoreline).

Multiple mark-recapture events, characterized by systematic sampling of lake shore zones on a daily basis, were conducted in all lakes except Harding during 1993 (Appendix B). In Harding Lake, a two-sample mark and recapture event was performed. In Volkmar Lake, sampling of the northern pike population continued on a daily basis for 7-days (14 May to 20 May); in T Lake, sampling was conducted for a 6 days (20 May to 25 May); and, in East Twin Lake, sampling lasted for the 5-day period from 24 May to 28 May. In Harding Lake, the marking event occurred over a three day period (1 June through 3 June), and after a three-day hiatus, was followed by a three-day recapture event (7 June through 9 June).

The Schnabel multiple-census method (Ricker 1975, pp. 96-100) of estimating abundance was used to estimate the abundance of the northern pike population and the associated standard error during the field activity in all lakes except Harding. The minimum sample size was achieved (and hence field sampling was soon terminated) when the relative precision (RP) of the abundance estimate approached the objective criteria ($\pm 25\%$). Recording length from all fish sampled more than adequately met sample sizes deemed necessary (Thompson 1987) to estimate the length composition, a series of multinomial proportions.

All lakes (except Harding) were divided into uniform sampling zones (by lakeshore distance) to evenly apportion sampling effort, and to allow for later testing of movement of marked fish between areas of release and recapture (Figures 2 to 5). The rationale behind establishing the size of the individual sampling zones was derived from the results of data collected in the Volkmar Lake telemetry study conducted during a similar time frame in 1991 (Pearse and Clark 1992). The median distance moved during single nightly periods for the radio-tagged northern pike (642 m), was divided into the circumference of Volkmar Lake (8,200 m) which resulted in 13 uniform sampling zones. The areas were labeled consecutively in a clockwise fashion from a

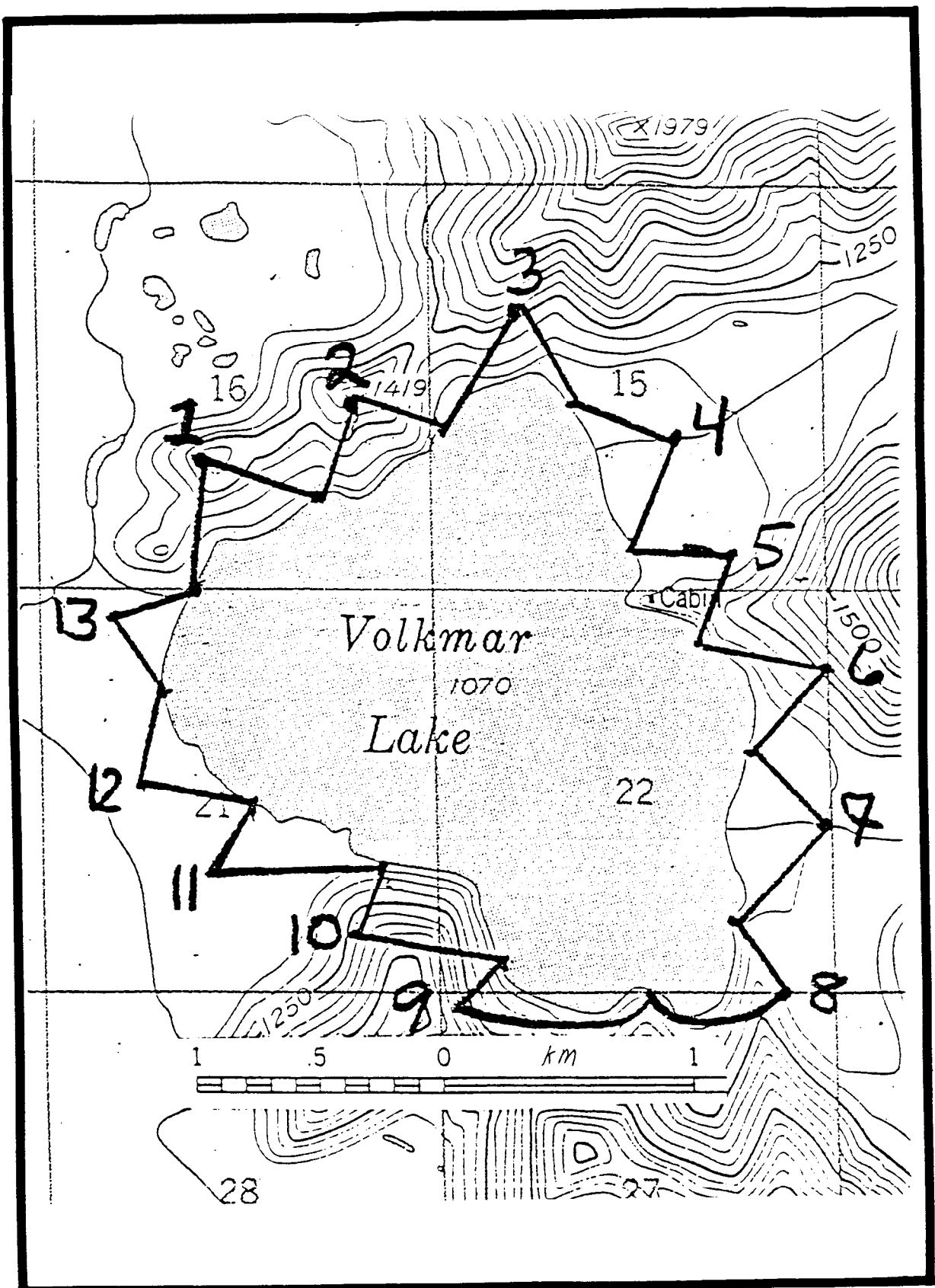


Figure 2. Volkmar Lake study area.

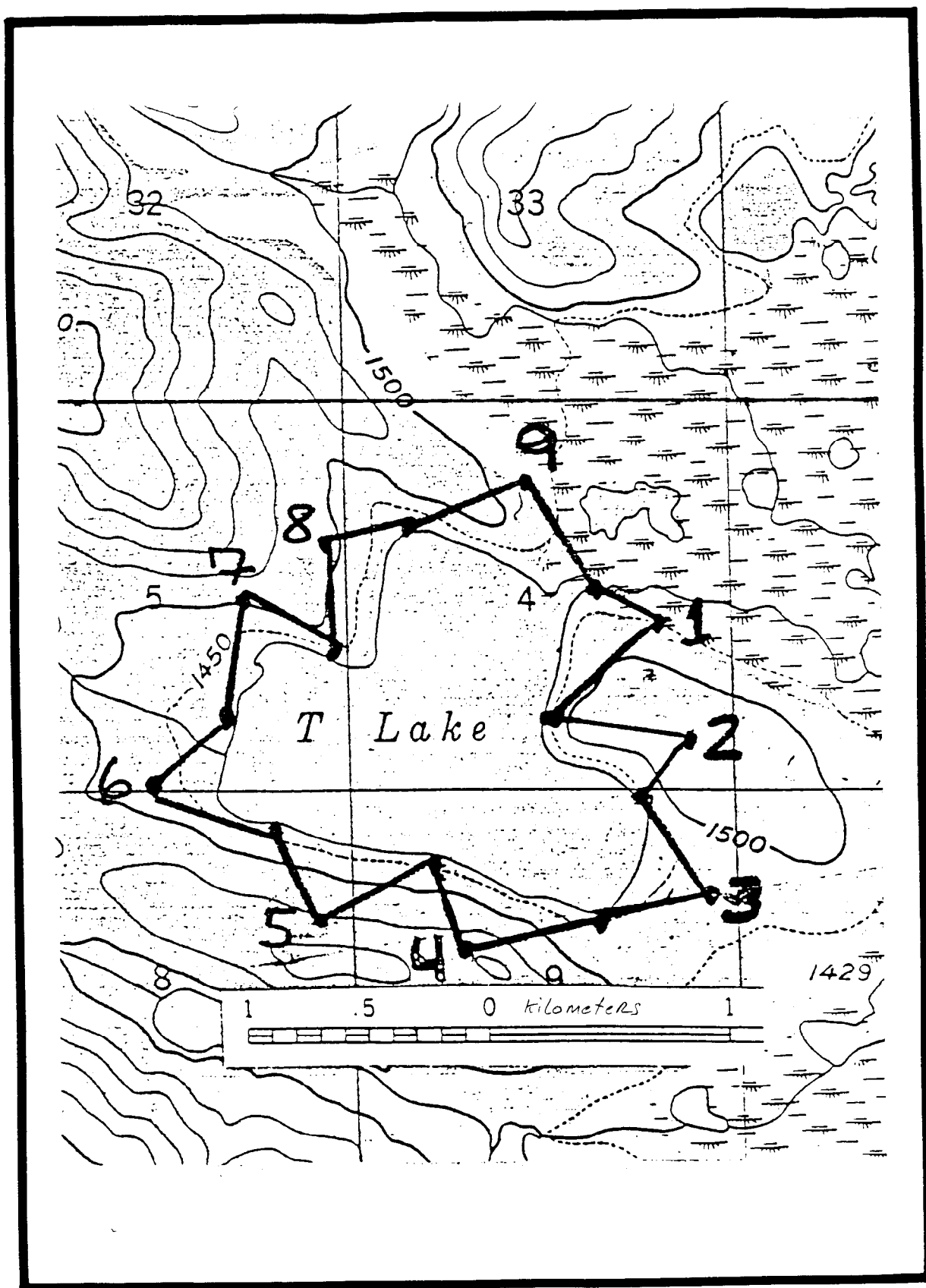


Figure 3. T Lake study area.

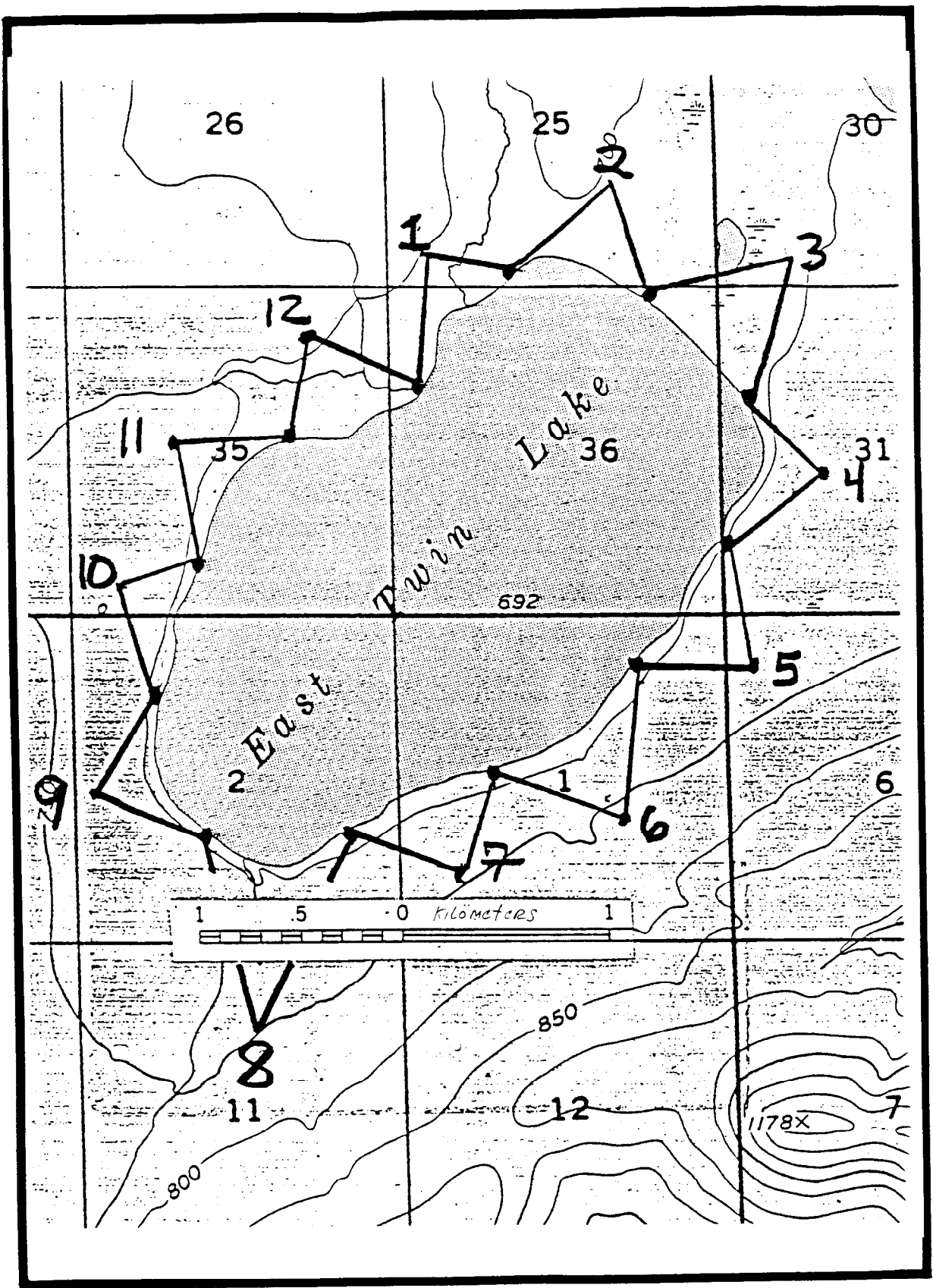


Figure 4. East Twin Lake study area.

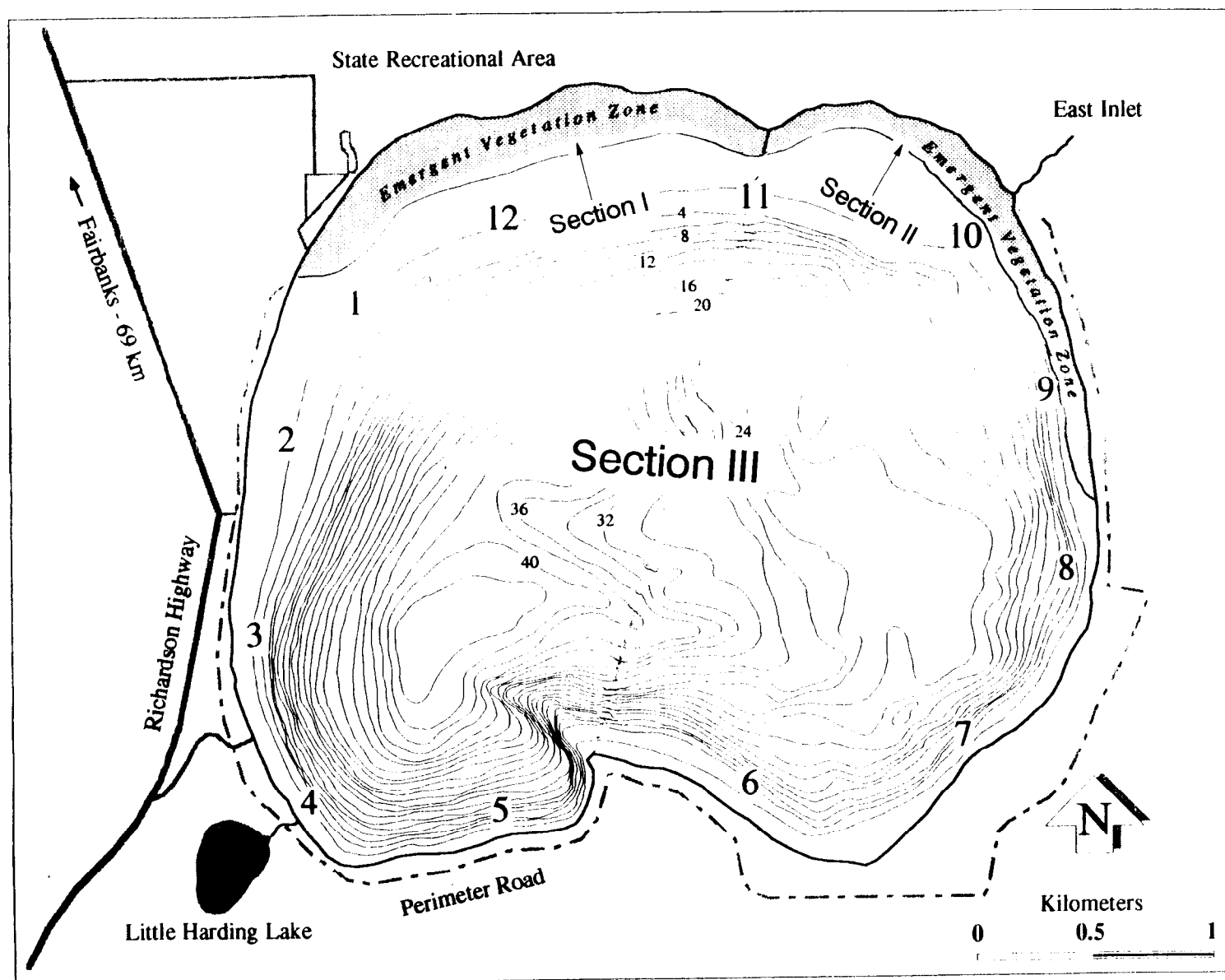


Figure 5. Harding Lake study area.

randomly selected starting point. Lakes T and East Twin were similarly divided into 650 m zones (T = 9 zones, 6,038 m; East Twin = 12 zones, 7,900 m). Harding Lake was divided into three non-uniform sampling zones, shown in Figure 5, to permit testing for the assumptions necessary to generate a two-event Petersen estimator with the methods described by Skaugstad and Burkholder (1992). Sampling was permitted at any near-shore location within a zone.

Fish were captured in Volkmar and East Twin lakes with a bag seine, 66 m long and 3 m deep, with 25 mm square mesh set from a boat and retrieved by hand to the shore by a crew of four or five. Seines were normally set in water less than 2 m deep, in known spawning and feeding areas, and usually within 100 m of the shore. Gill nets were used in T lake, and gill nets in combination with back-pack electrofishing units were used in Harding Lake to capture northern pike because of previous limited success with seines and traps in these waterbodies (Pearse 1990, and Skaugstad and Burkholder 1992). Six-panel 46 m gill nets, both floating and sinking, with two-each panels of 25, 38, and 51 mm bar mesh multifilament netting, dyed green, were set in near-shore spawning and movement areas. Up to nine nets were employed by a two-person crew during peak daily fish activity periods in T Lake. In Harding Lake, up to three gill nets were set in either of the two shallow sampling zone, and the electrofishing gear deployed adjacent to them to stimulate movement and enhance capture of nearby northern pike. In the third sampling zone (deeper than 1m), from six to 12 gill nets were deployed to capture moving northern pike. Frequent gill net checks (hourly) minimized handling mortality (for additional gear specifications and gear fishing patterns see Peckham and Bernard 1987).

Data Collection

Seine hauls or net-sets were numbered sequentially through the experiment, regardless of success of capture. Location of each haul or set was recorded on lake maps (Figures 2 to 5), with a separate map used each sampling day.

Past studies have shown that subsamples of length, sex, and age measurements from northern pike captured can be biased toward larger fish (Clark 1988). Therefore, each fish captured (including within-season recaptures) during daily sampling events was measured for FL to the nearest millimeter (mm), sex was recorded if determined by the extrusion of gametes (although not a program objective), and scale samples were taken. Northern pike were released in the approximate middle of the respective sub-area of capture to allow natural mixing behavior to occur.

All captured northern pike were examined for tags. All fish were examined for evidence of finclips and/or opercle punches, as fish captured in these long-term population studies have been double-marked to aid in detecting within and between year tag loss. Marking codes used in all lakes during 1993, plus those from prior sampling events, are detailed in Appendix C. Untagged northern pike judged to be in a healthy condition were released after being marked with a grey Floy FD-68B internal anchor tag (Floy Tag & Mfg., Inc., Seattle, WA.) inserted posteriorly at the left base of the dorsal fin during

all daily sampling events. In 1993, a second mark (dorsal punch, Option 5 = 3) was applied to all tagged fish in Volkmar, T, and East Twin lakes to later estimate the rate of tag loss from each capture event. In Harding Lake, the double mark consisted of either a left pectoral punch (Option 5 = 9), or right pectoral punch (Option 5 = 10), depending on whether the capture occurred during the marking or recapture event, respectively. The importance of identifying all current and previous punches/finclips (Appendix C) was impressed upon sampling teams.

Scales were removed from each fish regardless of capture occasion to estimate age. A minimum of three scales were taken from the preferred zone adjacent to, but not on, the lateral line above the pelvic fins as described by Williams (1955). Scales were then mounted directly on gummed cards marked (with litho-code number) to correspond with the respective field data form. The cards were used to make scale impressions on 20 mil acetate sheets using a Carver press at 137,895 kPa (20,000 psi) heated to 93°C for one minute. Scales were read on a microfiche reader (32x) and ages estimated in accordance with age identification criteria established by Williams (1955) and Casselman (1967). Because experience has shown that the formation of scale annuli in Alaskan stocks of northern pike generally coincides with the sampling period in late May, ages assigned corresponded to counts of annuli detected on the scales. A more detailed analysis of age interpretation based upon several body structures (scales, cleithra, and vertebrae) collected prior to the 1993 sampling program was presented by Pearse and Hansen (1992).

Data Analysis

Estimation of Abundance:

During the respective capture-recapture experiments, the preliminary estimates of abundance and associated Relative Precision (RP) of the estimate were calculated during the sampling process using the Chapman modification of the Schnabel mark/recapture population estimator (Ricker 1975) as follows:

$$\hat{N} = \frac{\sum (C_t M_t)}{\sum R_t + 1}; \text{ and,} \quad (1)$$

$$V[1/\hat{N}] = \frac{\sum R_t}{(\sum C_t M_t)^2}; \quad (2)$$

From the delta method:

$$V[\hat{N}] \approx V\left[\frac{1}{\hat{N}}\right] \hat{N}^4$$

where:

C_t = total sample taken on day t ;

M_t = total marked fish at large at the start of the day t (or other interval), i.e. the number previously marked less any previous mortalities; and,

R_t = number of fish recaptured in the sample C_t .

These confidence intervals were used to calculate the RP of the estimate as:

$$RP = \frac{1.96 * SE [N]}{N} 100 \quad (3)$$

Subsequent to database collection and editing, the 8 January, 1993 version of computer program CAPTURE (Rexstad and Burnham 1992) was employed along with other statistical tests to interactively develop the Maximum Likelihood Estimator (MLE) of northern pike abundance (N), its approximate standard error, and infer the quality of the estimate in Volkmar, T, and East Twin lakes. The underlying logic and statistical process of program CAPTURE is described in Otis et al. (1978), and White et al. (1978). White et al. (1982) further elaborated upon the use and applications of the program.

Estimation of population abundance using capture-recapture methods normally requires that four assumptions be met. The first assumption involves closure of the population while the estimation process is being conducted. Closure is normally divided into two components: geographic closure or boundaries that limit the fish population, and demographic closure to birth, immigration, death, and emigration. The assumption of closure was most likely met in all waterbodies due to the short period of sampling, and because no northern pike were observed entering or leaving the lakes studied that had outlets (T and East Twin). The second assumption, that tagged fish did not lose their marks between sampling events, was assured by double-marking sampled fish and noting tag loss. Within-season tag loss was minimal (<1%) in this study. Careful data collection assured that all marked fish were noted upon both mark and recapture, which fulfilled this third assumption. The fourth assumption, that every fish have a constant and equal probability of capture on each trapping occasion, and that marking does not affect subsequent catchability of the fish, may not have been met. The focal point of Otis et al. (1978) was to relax assumption four, and they therefore developed program CAPTURE to partially accommodate situations involving unequal catchability of marked and recaptured fish. The authors admit the fourth assumption usually is not met in the real course of sampling events.

The various models developed for which abundance estimators are available in CAPTURE (8 January 1993 version) are as follows:

1. Model M_0 : This is the most restrictive model and assumes capture probabilities to be constant through all sampling events, but does not allow capture probabilities to vary by individual (heterogeneity), or provide for individual behavior (trap happy or shy). Also called Estimator Null.
2. Model M_b : Allows capture probabilities to vary due to behavioral response, but not due to heterogeneity or temporal variation (by sampling event). It assumes every unmarked fish in the population has the same probability of capture during each event, and every marked fish has the same probability of recapture for all events subsequent to marking. Also called Estimator Zippin.
3. Model M_t : The original M_t . Allows capture probabilities to vary only by time or sampling event, but does not allow heterogeneity of individual capture probabilities or behavioral response. Also called Estimator Darroch.
4. Model Chao M_t : This is the updated estimator for M_t , which assumes capture probabilities vary with time. This modification (Chao 1989) reportedly performs well when probabilities of capture are small.
5. Model M_h : The original M_t . Allows heterogeneity but not behavioral response, and assumes each fish has its own unique capture probability which remains constant over all sampling events. Calculating population estimates by size, sex or age can apparently minimize heterogeneity of capture probabilities, if detected. Also called Estimator Jackknife.
6. Model Chao M_h : An updated estimator for M_h . Similar to M_h , this modified estimator (Chao 1988) is reportedly less biased when probabilities of capture are small.
7. Model Chao M_{th} : This model assumes capture probabilities vary with time and individual.
8. Model Burnham M_{tb} : This estimator assumes capture probabilities vary with time and behavioral effects (trap-happy or shy).
9. Model M_{bh} : Allows for both heterogeneity and trap response, and assumes each fish has its own unique pair of potential capture probabilities, referring to whether the fish is marked or unmarked, which remain constant over all sampling events.

Program CAPTURE neither directly accounts nor corrects specifically for size selectivity, if present (Dave Bernard, RTS, pers comm.). Model M_h was not indicated as the preferred estimator for the populations sampled in 1993. However, as a precaution dictated by prior estimates of stock abundance of northern pike populations in which size selectivity was frequently detected

(Pearse and Burkholder 1993), a further test was done to determine if size selectivity occurred during the sampling events in 1993. Plots of cumulative distribution functions (CDF) of daily lengths of captured northern pike were visually examined to note potential size bias of a biological significance (spatial separation of the plots). The outcome of this test determined if the abundance estimates needed to be stratified into different length groups, and abundance estimated separately for each stratum using program CAPTURE. In addition, the proportion of recaptured northern pike in the daily sample of captured fish versus the number of northern pike that were marked prior the daily sampling event were examined to detect changes in capture probability (Seber 1982, p. 145). A linear increase in the daily proportion of recaptured fish previously marked is expected to follow an increase in the number of marked fish at large, providing mixing of marked and unmarked fish occurs, or capture probabilities of all fish are uniform.

Based upon the combination of meeting the aforementioned assumptions, the output of program CAPTURE, and the results of additional tests for size selectivity described, the model was selected which best estimated the abundance of the respective population of northern pike in Volkmar, T, and East Twin lakes. All authors suggest caution is indicated when data are analyzed with program CAPTURE, as tests employed in the analysis and model selection are not independent, and often have low power especially for small populations. We feel that the populations and sample sizes we dealt with were sufficiently large enough to mitigate this problem.

For a two-sample Petersen mark-recapture experiment, used to estimate the abundance of northern pike in Harding Lake, assumptions for an unbiased estimator are: a closed population during the experiment (no recruitment through growth or immigration) and no loss of marks; and complete mixing of tagged and untagged fish or equal probability of capture for all individuals during either the first event (marking) or the second event (recapture). The mark-recapture experiment was designed to insure against failure of these assumptions, and where possible, statistical tests were conducted to determine if an assumption failed.

To conduct the statistical tests, Harding Lake was arbitrarily divided into three sections: two inshore and one offshore sampling zone (Figure 5). Inshore areas were shallow (less than 1 m) with emergent and submerged aquatic plants. Offshore areas were deeper (more than 1 m) with no emergent aquatic plants and few or no submerged aquatic plants. Northern pike were captured in zone 1 and 2 with electro-fishing gear and gill nets, and with gill nets in zone 3. The location of capture in Event 1 and Event 2 was recorded.

The population was closed to recruitment because the short time between sampling events (two days) minimized recruitment through growth. The absence of an outlet stream and the fish control structure at the inlet from Little Harding Lake eliminated recruitment through immigration. Each fish was given a finclip and a Floy tag. Clipped fins could not grow back during the short period of the experiment. Because a double mark was used, the rate of tag loss was estimated. Mixing between sections and between inshore and offshore

areas was evaluated with a separate contingency table constructed of numbers of marked northern pike that were and were not recovered during Event 2.

With a two-event mark-recapture experiment, equal probabilities of capture can be statistically tested only for the first event. Equal probabilities of capture during the second event can only be inferred from specifics of the first and second capture events and comparisons of stratified and unstratified estimates of abundance.

The abundance of northern pike 300 mm FL and longer was estimated using a modified Petersen mark-recapture estimator. The estimator and its approximate variance is from Seber (1982).

$$\hat{N} = \frac{(C+1)(M+1)}{(R+1)} - 1; \text{ and,} \quad (4)$$

$$\hat{V}[\hat{N}] = \frac{\hat{N}(C-R)(M-R)}{(R+1)(R+2)}; \quad (5)$$

where:

- C = number of fish captured during Event 2;
- M = number of fish marked and released alive during Event 1; and,
- R = number of marked fish recaptured during Event 2.

Composition Estimation:

Estimates of abundance were used to apportion northern pike populations into the following categories:

1. "Small" (300-449 mm), "Medium" (450-749 mm), "Large" (750 mm and larger), and "All northern pike greater than 299 mm or greater than 449 mm". This was done to facilitate annual comparisons among and between all lakes studied;
2. Relative Stock Densities (RSD; Gabelhouse 1984) in "stock" (300-524 mm), "quality" (525-654 mm), "preferred" (655-859 mm), "memorable" (860-1,079 mm), and "trophy" (> 1,079 mm) FL classes;
3. Length frequency of the sampled northern pike in 25 mm categories;
4. Abundance by age; and,
5. Mean length-at-age.

Composition estimates were calculated as follows:

$$\hat{p}_j = n_j/n \quad (6)$$

where:

n = the number of fish sampled for information on age or length composition;

n_j = the number of sampled fish in group j ; and,

p_j = the estimated fraction of the fish in group j .

The variance of the proportion was calculated as:

$$V[\hat{p}_j] = \frac{\hat{p}_j(1 - \hat{p}_j)}{n - 1} \quad (7)$$

The estimated number of northern pike by length group was calculated as:

$$\hat{N}_j = \hat{p}_j \hat{N} \quad (8)$$

The variance for \hat{N}_j was calculated as a sum of the exact variance of a product from Goodman (1960):

$$V[\hat{N}_j] = V[\hat{p}_j]\hat{N}^2 + V[\hat{N}]\hat{p}_j^2 - V[\hat{p}_j]V[\hat{N}] \quad (9)$$

Mean length-at-age by year reflects the mean value of summed lengths by age alone. Non-overlapping 95% confidence intervals were used to detect differences between estimates of abundance or estimated proportions.

RESULTS AND DISCUSSION

Volkmar Lake

Abundance Estimation:

The estimated abundance of northern pike (> 299 mm FL) during mid-May was 4,160 fish (SE = 605, RP = 29%). Density was estimated to have been 11.2 northern pike per ha (Appendix D). The level of RP (29%) was close to the criteria set forth in the operational plan (to be within 25% of the estimate) for the estimate of northern pike longer than 299 mm. The estimated abundance of northern pike > 449 mm was 3,097 fish (SE = 427, RP = 27%). Both estimates of abundance by size groups were statistically similar to those determined in 1992.

After seven days of sampling, the in-season estimate of abundance was 4,776 northern pike (SE = 703), essentially the same as that later suggested by program CAPTURE; the in-season estimate of RP (and hence SE) declined steadily from 68% on sampling day 3 to 29% on day 7.

As part of the model selection procedure, program CAPTURE used the daily capture history data as presented for Volkmar Lake in Appendix E. Included in Appendix F are the results of the model selection criteria, with the most appropriate model selected by CAPTURE having the maximum value. Program CAPTURE selected model Chao M_t which was accepted, as it seemed reasonable given prior estimates of abundance and sport harvest, and closely approximated the traditional Schnabel estimate determined in-season.

Size selectivity among sampling events proved insignificant. The daily CDF plots of fish lengths were biologically identical (Figure 6). Daily proportions of recaptured fish appeared to decline, in relation to those marked at large prior to the daily sampling event (R/M%, Appendix D), after sampling day 5. The R/C ratios increased then declined during the latter sampling events. Program CAPTURE detected a slight variability in the estimated probability of capture of all fish by sampling occasion, which ran from 0.02 to 0.03 throughout the study. Declining overall catch rates during population sampling linked to movement and habitat preferences of northern pike in Volkmar Lake have been previously documented by Pearse and Clark (1992). No evidence of tag loss was observed during the sampling events.

Composition Estimation:

The source for the 1993 estimates of composition was all unique fish examined in 1993, as size selectivity of the gear was not detected. The estimated 1993 abundance and proportion of northern pike in all size categories (Appendix D) were similar to that determined in 1992. The "Small" size category is mainly comprised of partially recruited northern pike, and contributed 29% of the population's makeup in 1993. Fish in the "Medium" size range have predominated in all years, and equalled 69% of the estimate in 1993. Fish over 749 mm contributed 5% of the overall estimate. Medium and Large sized northern pike consist primarily of fish fully recruited to the spawning population. In Volkmar Lake, male northern pike are generally absent from the Large size category (Pearse 1991).

Estimated RSDs (Appendix G) indicated the stock and quality categories predominated, with few if any captured in the memorable and trophy size groups. The 1993 composition is similar that detected in 1988, when the beginning of a two-year reduction in estimated abundance of northern pike from 300 to 449 mm was noted (Appendix D; and, Pearse 1991).

The length frequency distribution of sampled northern pike (sexes combined), described in Appendix H, is similar to 1992. Approximately 50% of the fish sampled were shorter than 550 mm, and about 90% of the northern pike captured were less than 700 mm. Of fish captured in 1993, none died during the normal course of sampling events.

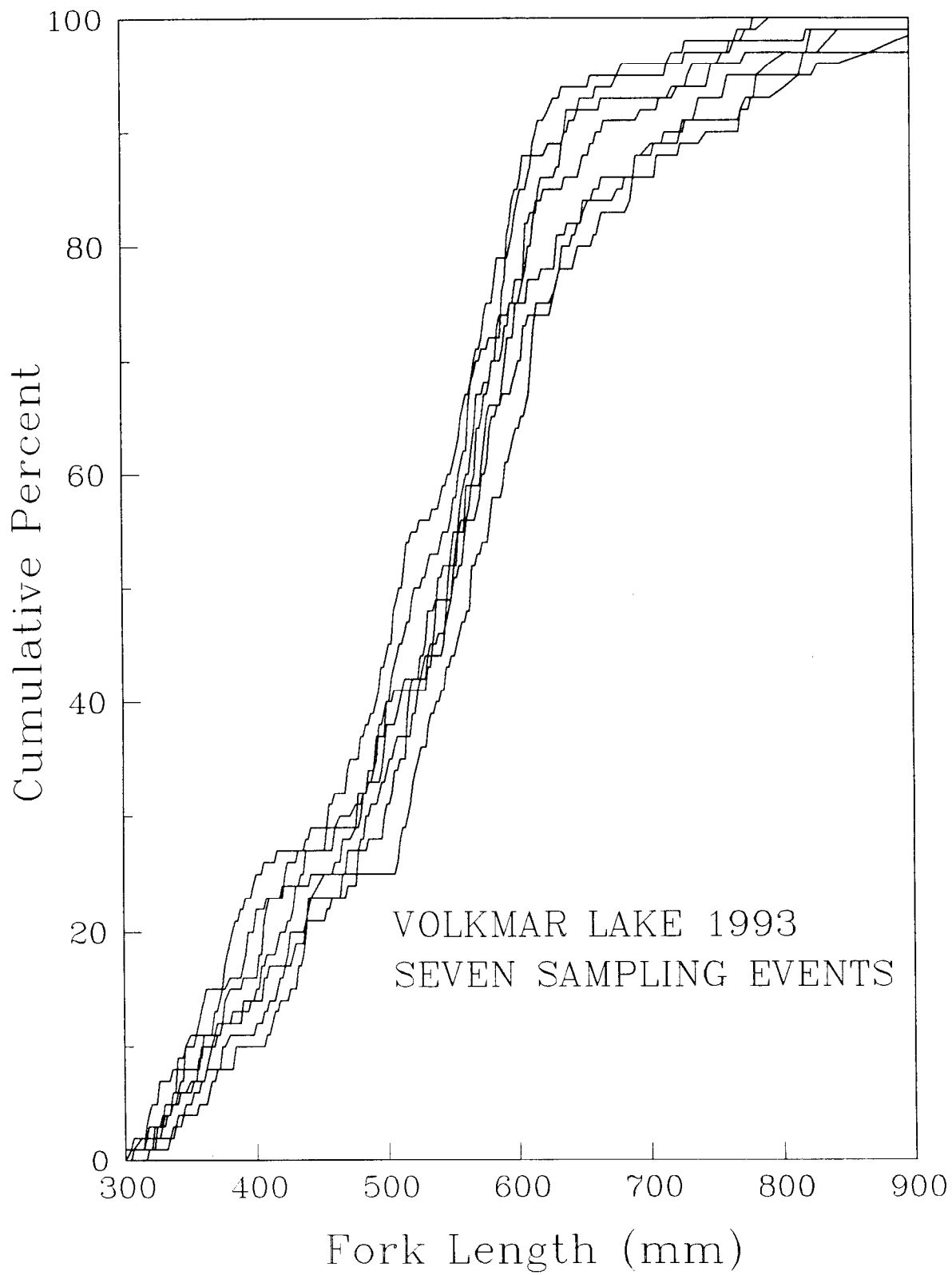


Figure 6. Daily cumulative length distribution frequencies of northern pike captured in Volkmar Lake, 1993.

In 1993, the age 5 cohort had the highest abundance ($N = 886$, $SE = 149$) in the sex-combined data (Appendix I). Sex composition is no longer an objective for this study. The mean length-at-age data (Appendix J) indicates increasing length with increasing age, as indicated in prior samples.

T Lake

Abundance Estimation:

The estimated abundance of northern pike (> 299 mm) in T Lake during late May was 853 fish ($SE = 137$, $RP = 31\%$). Density was estimated to have been 5.4 northern pike per ha (Appendix D). The level of RP (31%) did not meet the criteria set forth in the operational plan (to be within 25% of the estimate of northern pike greater than 299 mm). The estimated abundance of northern pike > 449 mm was 734 fish ($SE = 113$, $RP = 30\%$). Relatively cool, cloudy weather experienced during the early portion of the sampling period in 1993 may have led to lower than expected rates of capture and elevated level of RP (Appendix E). Estimates of abundance were statistically similar to those determined in 1992.

After six days of sampling, the in-season estimate of abundance ($N = 780$, Schnabel estimator) duplicated that later suggested by program CAPTURE; the in-season estimate of RP (and hence SE) declined steadily from 85% on sampling day 2 to 30% on day 6.

As part of the model selection procedure, program CAPTURE used the daily capture history data as presented for T Lake in Appendix E. Also included are the results of the model selection criteria, with the most appropriate model selected by CAPTURE having the maximum value. Program CAPTURE selected model Chao M_t (time specific changes in capture probabilities) first, and model M_{tbbh} (time specific, behavioral, and heterogenetic changes in capture probabilities) second; the version of CAPTURE we used does not provide an estimator for the latter. I accepted M_t with qualifications as described below.

Tests for gear selectivity among sampling events appeared significant in one test. The daily CDF plots of fish lengths appeared biologically identical except for Day 6 (Figure 7). In addition, the daily proportions of recaptured fish increased in a normal linear fashion, then declined sharply on sampling day 6 (Appendix E). The cause is unknown, but has been observed previously in this body of water. Day six was therefore eliminated from the analysis and data set used to estimate abundance and composition. No tag loss was detected during the sampling program.

Composition Estimation:

The source for the 1993 estimates of composition was all unique fish examined in 1993, excluding those captured on day six. As indicated in Appendix D, the estimated 1993 abundance and proportion of northern pike in the Small category ($N = 119$, $SE = 27$) was similar to that determined in 1992 ($N = 74$, $SE = 15$).

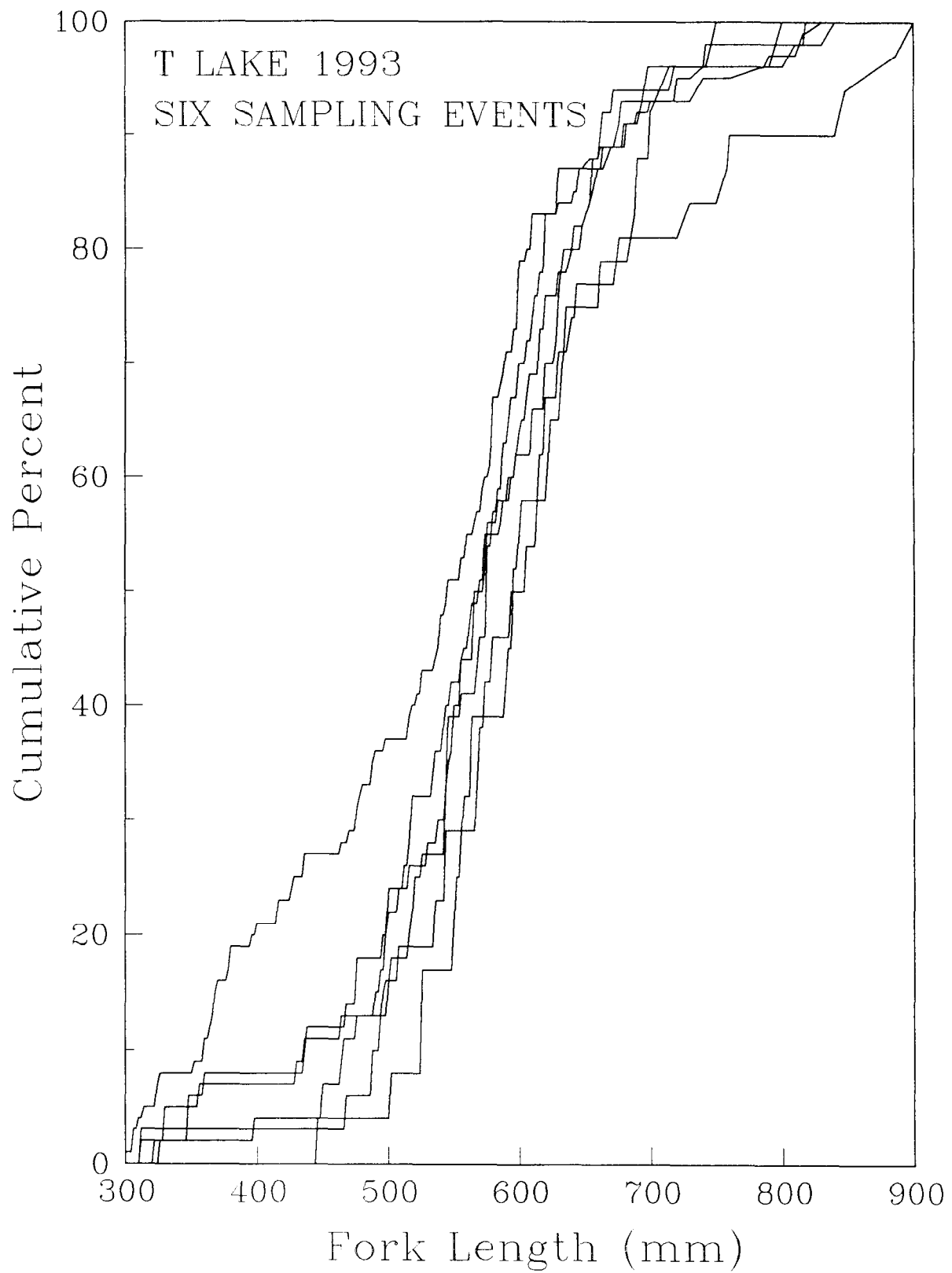


Figure 7. Daily cumulative length distribution frequencies of northern pike captured in T Lake, 1993.

The abundance of Medium sized northern pike ($N = 668$, $SE = 112$) was also similar to that determined in 1992 ($N = 665$, $SE = 66$). The estimated abundance of northern pike in the Large size category ($N = 48$, $SE = 14$) was also similar to that determined in 1992 ($N = 42$, $SE = 11$). The Small size category (300 to 449 mm) is mainly comprised of partially recruited northern pike. Unlike northern pike in other lakes studied, fish in T Lake probably do not recruit to the spawning population (and sampling gear) at as small a size or at as high a rate (Pearse 1991). Therefore, as in prior years, fish in the Medium size (> 449 mm) range predominated in T Lake. Medium and Large northern pike consist primarily of fish fully recruited to the spawning population. In T Lake, male northern pike are generally absent from the Large size category (Pearse 1991).

Estimated RSDs (Appendix G) indicated the quality category (525 to 654 mm) was dominant, with few captured in the memorable and above size groups. The RSD composition was essentially the same in 1993 as in 1992.

The length frequency distribution of sampled northern pike (sexes combined) is described in Appendix K. The distribution was similar to 1992, with some small changes in proportions. Approximately 50% of the fish sampled were smaller than 575 mm, and about 90% of the northern pike captured were less than 700 mm in 1993, as in 1992.

In 1993, the age 5 cohort was highest in abundance ($N = 331$, $SE = 60$), both sexes combined, likely indicating good recruitment. Sex composition is no longer an objective for this study. Age 6 through 8 northern pike have dominated in previous years. The mean length-at-age data (Appendix M) indicates increasing length with increasing age.

East Twin Lake

Abundance Estimation:

The sampling effort in 1993 lasted five days, and was the second intensive look at the northern pike population in this popular recreational waterbody. The abundance of northern pike (> 299 mm) in late May was estimated at 6,070 fish ($SE = 757$, $RP = 24\%$). Density was estimated to have been 11.5 northern pike per ha (Appendix D). The estimated abundance of northern pike > 449 mm was 4,766 fish ($SE = 589$). The level of RP met the criteria set forth in the operational plan (to be within 25% of the estimate of northern pike greater than 299 mm).

After five days of sampling, the in-season estimate of abundance ($N = 5,610$, Schnabel estimator) came within 460 fish of that later suggested by program CAPTURE; the in-season estimate of RP (and hence SE) declined steadily from 69% as soon as sampling day 2 to 24% on day 5. The criteria of RP was met on sampling day 5.

As part of the model selection procedure, program CAPTURE used the daily capture history data as presented for East Twin Lake in Appendix E. As for other lakes, included are the results of the model selection criteria, with

the most appropriate model selected by CAPTURE having the maximum value. Program CAPTURE selected model Chao M_t (time specific changes in capture probabilities) first, and model M_{th} (time specific and heterogenous changes in capture probabilities) second. I accepted M_t with qualifications as described below.

Tests for gear selectivity among sampling events proved insignificant in all tests. The daily CDF plots of fish lengths were somewhat similar (Figure 8). Daily proportions of recaptured fish increased in a normal linear fashion until day five (Appendix E). No tag loss was detected in this study.

Composition Estimation:

The source for the 1993 estimates of size and age composition of northern pike in East Twin Lake was all unique fish examined in 1993. As indicated in Appendix D, the estimated proportion in 1993 of northern pike in the Small category was 0.22 (SE = 0.013), and was a decline from that estimated for 1992 (0.33, SE = 0.014). Northern pike in this size category are only partially recruited to the population of mature fish, so variability in estimates of annual abundance is expected and is probably determined both by cohort strength and behavior related to reproductive activity. Medium-sized northern pike (N = 4,668, SE = 588) were dominant; their proportion (0.76, SE = 0.014) was greater than that found during 1992 (0.66, SE = 0.014). High proportions of northern pike in this size category is expected in our sampling program. This likely indicates size at initial maturity occurs (along with recruitment to our sampling gear) at a length within the lower bounds of the size category (> 449 mm), as opposed to the upper limits of the Small size category (< 450 mm). The estimated proportion of northern pike in the Large size category (N = 98, SE = 28; 2%), is in the lower range of proportions (1 to 11% for all lakes) found for this size group of northern pike in comparison with other waterbodies (Appendix D). Due to their low abundance, proportions of northern pike in this category vary more on an annual basis as a function of the relative abundance of fish in other size groups, than by the abundance of northern pike in the Large category alone.

The age composition of northern pike sampled during 1993 in East Twin Lake, presented in Appendix N), indicates fish between age 2 and age 19 were captured. Age 5 northern pike dominated (0.30, SE = 0.018) the composition, as in 1993. Based upon age composition studies in other lakes (Pearse 1991), this is likely the age at which the majority of fish reach maturity and/or become available to the sampling gear. Sixty one percent of the northern pike were assigned age 5 or younger for the years 1992 and 1993. The mean length-at-age was estimated at 514 mm (SE = 3) for age 5 fish (Appendix O). The largest fish captured measured 1,100 mm.

Estimated RSDs (Appendix G) indicated the stock category (300 to 525 mm) was dominant (53%) again in 1993, with few captured in the memorable and trophy size categories. A high percentage in the stock category is probably a good indicator of continued strong recruitment, but the database is too limited to predict future levels.

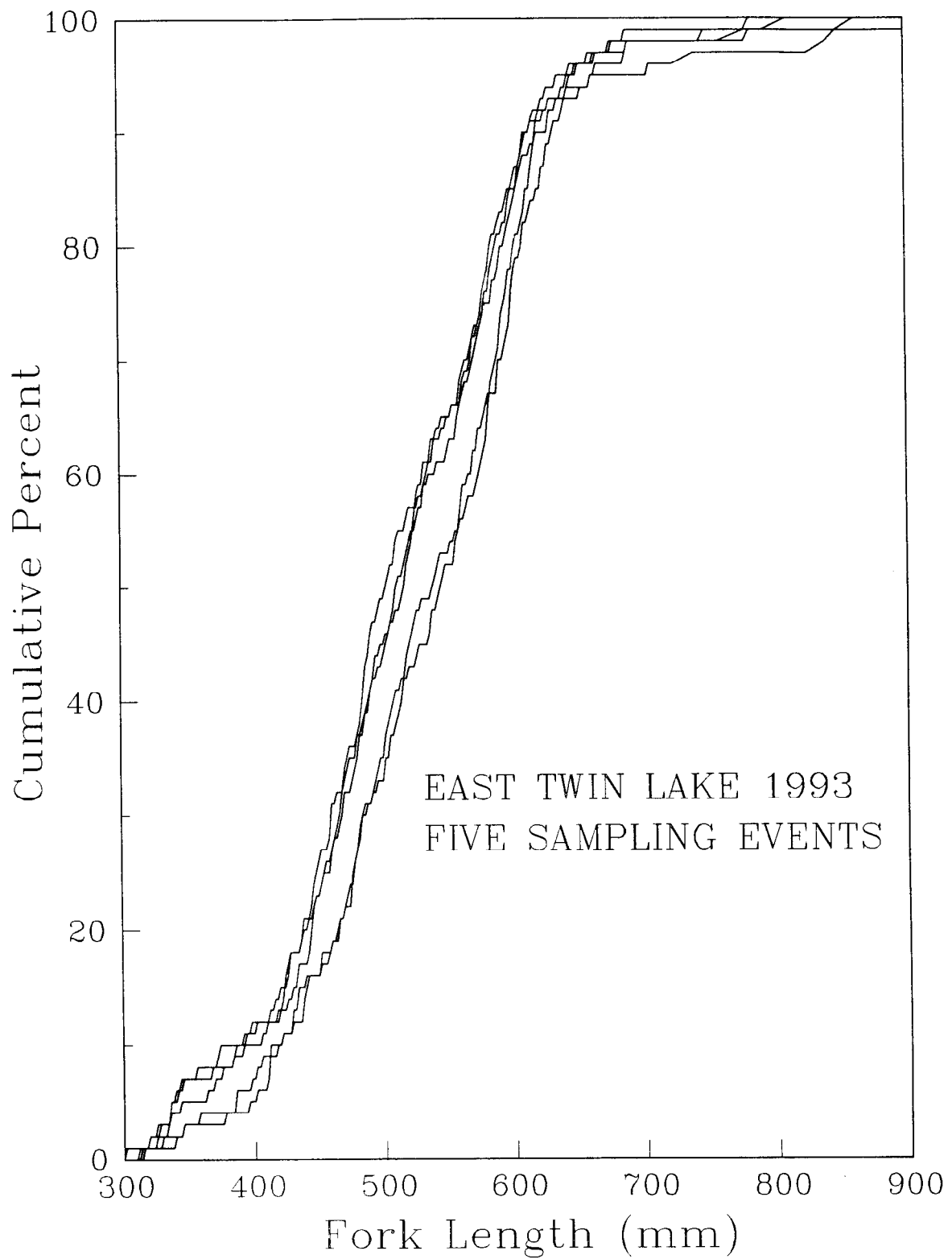


Figure 8. Daily cumulative length distribution frequencies of northern pike captured in East Twin Lake, 1993.

The historic length frequency distribution of sampled northern pike (sexes combined) is described in Appendix P. Approximately 42% of the fish sampled were shorter than 500 mm, and about 90% of the northern pike captured were less than 600 mm in 1993. The length composition was very similar to that determined in 1992, with the majority of fish lengths sampled being between 425 and 600 mm.

Of fish captured in 1993, none died through the normal course of sampling events. All fish captured appeared healthy, and had spawned by the time of sampling in late May.

Harding Lake

Abundance Estimation:

The estimated abundance of northern pike (> 299 mm) during early June was estimated to be 3,768 fish (SE = 432, RP = 23%). Density was estimated to have been 3.8 northern pike per ha (Appendix D). The level of RP met the criteria set forth in the operational plan (to be within 25% of the estimate of northern pike greater than 299 mm). The estimated abundance of northern pike > 449 mm was 2,479 fish (SE = 307, RP = 24%). The overall estimate of abundance was statistically similar between 1992 and 1993.

A two-event mark-recapture experiment was used to develop an estimate of abundance in 1993. During the first event, 581 northern pike were captured, marked, and released. During the second event, 368 northern pike were captured and examined for marks. Of these fish, 56 were marked.

The following results were used to select an appropriate abundance estimator and to determine appropriate methods for estimating length compositions. Tests for size selectivity proved negative. Length distributions of northern pike captured in Event 1 and recaptured in Event 2 were not different ($P = 0.0493$, $D = 0.19$). Length distributions of northern pike captured in Event 1 and Event 2 also were not biologically different (Figure 9). These tests indicated that there was no size selectivity during either the first or second events. Therefore, lengths from both events were used to estimate proportions for various estimates of length compositions.

Tests of assumptions for the Petersen abundance estimator were also met. Tag loss and sampling mortality was minimal, and the short interval between events assured population closure. During Event 2, 86 northern pike were captured in Area I (19 marked and 67 unmarked), 177 northern pike were captured in Area II (21 marked and 156 unmarked), and 105 northern pike were captured in Area III (16 marked and 89 unmarked). Since fractions of northern pike with marks captured during the second event (the R/C ratio) were not significantly different among the three lake sampling areas ($\chi^2 = 4.69$, $df = 2$, $P = 0.096$), it was concluded that either marked fish mixed completely between events, or probabilities of capture during the first event were the same throughout the lake.

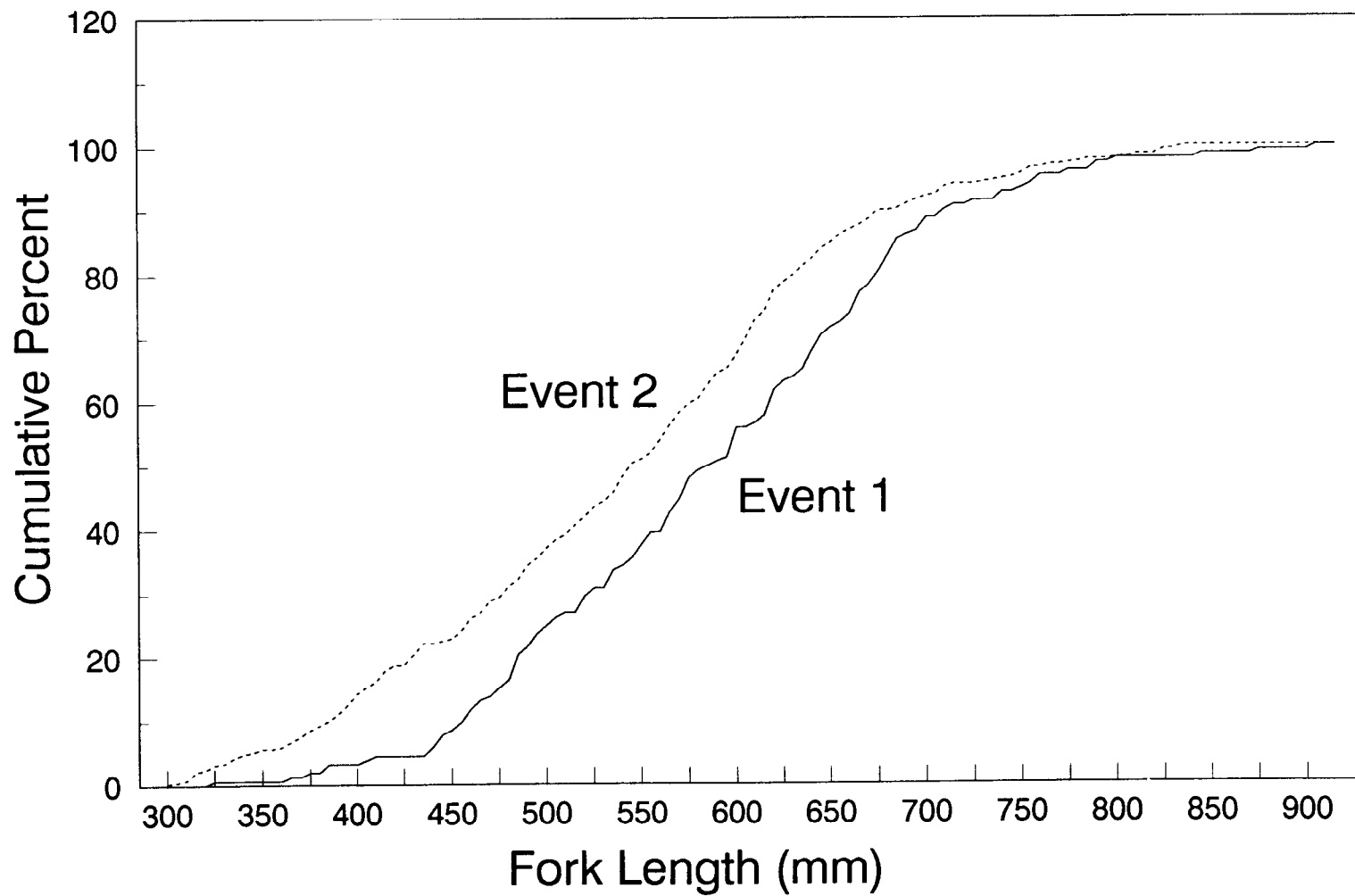


Figure 9. Daily cumulative length distribution frequencies of northern pike captured in Harding Lake, 1993.

Composition Estimation:

The source for the 1993 estimates of composition was all unique fish examined in 1993. Estimates of abundance for northern pike in the Medium size category (2,621, SE = 306) were higher in 1993 than in 1992 (1,430, SE = 159) as shown in Appendix D. Strong recruitment continued for fish in the Small size category. The Small size category (300 to 449 mm) is mainly comprised of partially recruited northern pike. As in prior years, fish in the Medium size range predominated in Harding Lake. Medium and Large northern pike consist primarily of fish fully recruited to the spawning population.

The age composition of northern pike sampled during 1993 in Harding Lake, presented in Appendix Q, indicates fish between age 2 and age 13 were captured. Age 4 northern pike dominated (0.30, SE = 0.016) the composition, as in 1992. The mean length of the age 4 fish was estimated at 481 mm in 1993. Based upon composition studies in other lakes (Pearse 1991), this is likely the age and size at which the majority of fish reach maturity and/or become available to the sampling gear. Forty-seven percent of the northern pike were assigned age 4 or younger in 1993, compared with approximately 50% in 1992. In contrast, only 13% of the sample were age 4 and younger in 1991, likely indicating poor recruitment for that year.

Estimated RSDs (Appendix G) indicated the stock category (300 to 525 mm) was dominant, with few captured in the memorable and above size groups. The abundance of northern pike in the stock category in 1993 was similar to the 1992 estimate.

Of fish captured in 1993, 11 died through the normal course of sampling events. No incidence of unhealthy northern pike was observed.

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Appendix A

Appendix A. Recreational fishing effort, harvest, and exploitation of northern pike in Volkmar, T, East Twin and Harding lakes, by year.

Lake	Angler Days ^a	Angler Days Per Ha	Harvest of Northern Pike ^a	Harvest Per Angler Day	Estimated Abundance of Northern Pike > 299 mm	Estimated Exploitation Rate if Harvested Fish were > 299 mm	Estimated Abundance of Northern Pike > 449 mm	Estimated Exploitation Rate if Harvested Fish were > 449 mm
<u>Volkmar</u>								
1981	458	1.7	648	1.4				
1982	546	2.0	777	1.4				
1983	270	1.0	430	1.6				
1984	436	1.6	428	1.0				
1985	711	2.6	503	0.7			4,020	0.13
1986	596	2.2	657	1.1	8,056	0.08	4,028	0.16
1987	472	1.7	224	0.5	6,932	0.03	4,230	0.05
1988	186	0.7	255	1.4	2,766	0.09	2,196	0.12
1989	466	1.7	180	0.4	1,330	0.14	1,115	0.16
1990	129	0.5	84	0.7	4,038	0.02	2,019	0.04
1991	1,052	3.9	565	0.5	4,510	0.13	2,509	0.23
1992	608	2.2	231	0.4	3,888	0.06	2,542	0.09
Mean	494	1.8	415	0.8	4,503	0.07 ^b	2,832	0.12 ^b
<u>T</u>								
1989	67	0.4	60	0.9	298	0.20	271	0.22
1992	--		--					
<u>East Twin</u>								
1983	388	0.7	839	2.2				
1984	87	0.2	208	2.4				
1985	104	0.2	0	0.0				
1986	76	0.1	24	0.3				
1987	398	0.8	66	0.2				
1988	637	1.2	346	0.5				
1989	765	1.5	832	1.1				
1990	1,035	2.0	760	0.7				
1991	679	1.3	625	0.9				
1992	950	1.8	546	0.6	7,449	0.07	5,016	0.11
Mean	512	1.0	425	0.8				

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Appendix A. (Page 2 of 2).

Lake	Angler Days ^a	Angler Days Per Ha	Harvest of Northern Pike ^a	Harvest Per Angler Day	Estimated Abundance of Northern Pike > 299 mm	Estimated Exploitation Rate if Harvested Fish were > 299 mm	Estimated Abundance of Northern Pike > 449 mm	Estimated Exploitation Rate if Harvested Fish were > 449 mm
<u>Harding</u>								
1983	708	0.7	178	0.3				
1984	1,707	1.7	766	0.5				
1985	850	0.9	503	0.6				
1986	2,064	2.1	673	0.3				
1987	5,125	5.1	1,886	0.4				
1988	3,256	3.3	2,092	0.6				
1989	4,935	4.9	1,764	0.4				
1990	3,895	3.9	591	0.2	---	---	1,283	0.46
1991	5,155	5.2	1,888	0.4	2,308	0.81	1,527	1.00
1992	5,086	5.1	341	0.1	2,868	0.12	1,496	0.23
Mean	3,276	3.3	1,068	0.3	2,588	0.43	1,435	0.66

^a Data source: Mills 1979-1993, Mills pers comm. 1992.

^b Includes 1986-1992 data only.

^c Includes 1987-1992 data only.

APPENDIX B

Appendix B. Sampling dates and abundance estimate types for Volkmar, T, East Twin and Harding lakes.

		Dates	Type Estimate	Comments
<u>Volkmar Lake:</u>				
1985	Mark Event	5/31-6/6	Stratified Petersen (> 449 mm FL)	No recaps < 450 mm.
	Recapture Event	6/17-6/19	(1) 450 - 699 mm	Gear selectivity for large
	11-day hiatus		(2) > 699 mm	fish with gill nets noted.
1986	Mark Event	6/3-6/6	Stratified Petersen	Gear selectivity occurred for
	Recapture Event	6/16-6/19	(1) < 450 mm	large fish with gill nets
	10-day hiatus		(2) 450-749 mm	(also seines/traps used;
			(3) ≥ 750 mm	not selective).
1987	Mark Event	5/19-5/25	Stratified Petersen	Beach seine used
	Recapture Event	5/27-5/29	(1) 300-549 mm (Darroch)	(some gillnetting).
	2-day hiatus		(2) 550-649 mm (Darroch)	Sampling gears selective
			(3) ≥ 650 mm (Petersen)	for large fish.
				Large fish (3) didn't mix.
1988	Mark Event 1988	5/23-5/31	Two-Season Stratified Petersen	Seines used from this year on.
	Recapture Event	1989	(1) 300-525 mm (Robson/Flick)	Insufficient fish captured to
			(2) 526-675 mm (Petersen)	do a within-season estimate.
			(3) ≥ 676 mm (Petersen)	
1989	Mark Event 1989	5/19-5/29	Two-Season Petersen	Insufficient captures during 1989
	Recapture Event	1990	(Robson/Flick)	for within-season estimates.
				Case IV B for composition estimates.
1990	Mark Event	5/16-5/19	Unstratified Petersen	Case IV B for composition estimates.
	Recapture Event	5/22-5/24		
	3-day hiatus			
1991	Mark Event	5/20-5/25	Petersen	Case IV B for composition estimates.
	Recapture Event	5/28-5/30		
	3-day hiatus			
1992	Capture-Recap- ture Event	6/2-6/9	m _t (Program Capture) Unstratified	
1993	Capture-Recap- ture Event	5/14-5/20	m _t (Program Capture) Unstratified	None

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Appendix B. (Page 2 of 3).

	Dates	Type Estimate	Comments
<u>"T" Lake:</u>			
1986	Mark Event 5/30-6/1	Stratified Petersen (> 450 mm FL)	No recaps < 450 mm.
	Recapture Event 6/11-6/12	(1) 450-749 mm	Gill nets size selective
	10 day hiatus	(2) ≥ 750 mm	for large fish.
			Mixing okay.
1987	Mark Event 5/27-5/29	Petersen	Mix okay; no length bias
	Recapture Event 6/1-6/3	(1) 300-449 mm	(stratified to simplify
	3-day hiatus	(2) 450-749 mm	comparison between years only).
		(3) ≥ 750 mm	
1988	Mark Event 5/18-5/21	Petersen	Mixing sufficient, no size bias
	Recapture Event 5/23-5/28		detected.
	2-day hiatus		
1989	Mark Event 5/18-5/26	2 season Petersen	1990 Recap event.
	Recapture Event 1990	(Robson/Flick)	Insufficient captures
			to do 1988 estimate.
1990	Mark Event 5/18	Petersen	Case II
	Recapture Event 5/20-5/21		Composition estimate.
	1-day hiatus		
1991	Mark Event 5/20-5/21	Stratified Petersen	Composition weighted by area abundance
	Recapture Event 5/24-5/25	By Area	and summed across area strata
1992	Capture-Recap- ture Event 6/1-6/6	m_L (Program Capture) Unstratified	
1993	Capture-Recap- ture Event 5/20-5/25	m_L (Program Capture) Unstratified	
<u>East Twin:</u>			
1992	Capture-Recap- ture Event 6/6-6/10	m_L (Program Capture) Unstratified	
1993	Capture-Recap- ture Event 5/24-5/28	m_L (Program Capture) Unstratified	

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Appendix B. (Page 3 of 3).

		Dates	Type Estimate	Comments
<u>Harding Lake</u>				
1990	Mark Event	5/14-5/25	Petersen	For fish ≥ 450 mm only
	Recapture Event	5/29-5/31		See Burkholder (1991)
1991	Mark Event	5/28-5/31	Petersen	For fish ≥ 300 mm
	Recapture Event	6/3-6/7	Unstratified	See Skaugstad and Burkholder (1992)
1992	Mark Event	5/26-6/9	Petersen	See Burkholder (1992)
	Recapture Event	6/15-6/18	Stratified	For fish ≥ 550 mm
1993	Mark Event	6/1-6/3	Petersen	No size selectivity
	Recapture Event	6/7-6/9	Unstratified	

Appendix C. Finclips and tags assigned to northern pike in Volkmar, T, East Twin, and Harding lakes, by year.

Year	Tag Series ^c	Color ^a	Finclips ^b	Comments
<u>Volkmar Lake</u>				
1983	16189 - 16196	Red	None	
	174 - 214	Blue		
1984	16207 - 16347	Red	None	
1985	16431 - 17568	Red	None	
1986	3000, 4000 series	Yellow	016, 032	032 = fish > 499 mm;
	16000, 17000 series	Red	Many odd combos	mostly untagged fish during marking run; mostly tagged fish during recap run.
	20400 - 20454	White		016 = fish < 500 mm; most tagged. Odd 16000, 17000 series tags from previous years.
1987	25000 - 26037	White	008	
			Many odd combos	
1988	98000 - 98355	Green	064	
			Many odd combos	
1989	21000 - 21383	Green	Option 5 = 2	Left opercle punch
1990	50000 - 50516	Blue	Option 5 = 1	Right opercle punch
1991	50517 - 50999	Blue	Option 5 = 4	Dorsal fin clip
	51000 - 51307	Blue	Same	
1992	03003 - 03442	Grey	Option 5 = 8	Anal fin clip
1993	03450 - 03924	Grey	Option 5 = 3	Dorsal punch
<u>T Lake</u>				
1986	3247 - 3618	Yellow	002	002 = accidental
			004	wrong clip; 004 =
			032	Mark Run; 032 =
				Recap Run.
1987	17569 - 17834	Red	008	
1988	99000 - 99139	Green	064	
1989	20000 - 20017	Green	Option 5 = 2	Left opercle punch
	20050 - 20058	Green	Same	
1990	59000 - 59055	Blue	Option 5 = 1	Right opercle punch
	59100 - 59126	Blue	Same	
1991	59250 - 59299	Blue	Option 5 = 4	Dorsal fin clip
	59344, 59346-7	Blue	Same	
	59349	Blue	Same*	
1992	06000 - 06194	Grey	Option 5 = 8	Anal fin clip
1993	06200 - 06329	Grey	Option 5 = 3	Dorsal Punch

-continued-

APPENDIX C

Appendix C. (Page 2 of 2).

Year	Tag Series ^c	Color ^a	Fin Clips ^b	Comments
<u>East Twin</u>				
1992	00000 - 01198	Grey	Option 5 = 8	Anal fin clip
1993	51550 - 52387	Blue	Option 5 = 4	Dorsal Clip
<u>Harding</u>				
1990	62765 - 63984	Blue	002, 004	See Burkholder (1991)
1991	64000 - 64999	Blue	008, 009	See Skaugstad (1992)
1992	49 - 1053	Yellow	Various	See Skaugstad (1992)
1993	48000 - 48868	Grey	Option 5=9	Left pectoral punch (Mark)
			Option 5=0	Right pectoral punch (Recapture Event)

^a Color Codes: 01 = Not Checked, 02 = Yellow, 03 = Green, 04 = White, 05 = Red, 06 = Blue, 08 = Grey.

^b Fin Clip Codes: 001 = Adipose, 002 = R. Pelvic (Ventral), 004 = L. Pelvic (Ventral), 008 = R. Pectoral, 016 = L. Pectoral, 032 = U. Caudal, 064 = L. Caudal, Option 5 = 2 = Left opercle punch, Option 5 = 1 = Right opercle punch, Option 5 = 8 = Anal fin clip.

^c Tag series may not indicate the total number of tags applied.

APPENDIX D

Appendix D. Abundance and density of various size groups of northern pike (> 299 mm FL) in Volkmar, T, East Twin and Harding lakes, by year.

Lake/ Year	Small (300-449 mm)				Medium (450-749 mm)				Large (Larger than 749 mm)				All (Larger than 299 mm)			All (Larger than 449 mm)				
	Abundance		Proportion		Abundance		Proportion		Abundance		Proportion		Abundance		Density	Abundance		Proportion		Density
	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	(Fish/Ha)	Estimate	SE	Estimate	SE	(Fish/Ha)
<u>Volkmar</u>																				
1985	---	---	---	---	3,732	201	---	---	288	24	---	---	---	---	---	4,020	250	---	---	---
1986	4,028	2,266	0.50	0.006	3,891	584	0.48	0.006	137	65	0.02	0.001	8,056	2,915	21.6	4,028	587	0.50	0.006	10.8
1987	2,703	641	0.39	0.006	4,118	634	0.59	0.006	111	22	0.02	0.002	6,932	1,542	18.6	4,230	634	0.61	0.006	11.3
1988	570	64	0.21	0.008	2,135	147	0.77	0.008	61	19	0.02	0.003	2,766	177	7.4	2,196	148	0.79	0.008	5.9
1989	215	43	0.16	0.010	974	177	0.73	0.012	141	30	0.11	0.008	1,330	240	3.6	1,115	179	0.84	0.010	3.0
1990	2,019	372	0.50	0.026	1,866	346	0.46	0.026	153	48	0.04	0.010	4,038	714	10.8	2,019	349	0.50	0.028	5.4
1991	2,001	253	0.44	0.018	2,276	285	0.51	0.018	233	46	0.05	0.008	4,510	541	12.1	2,509	289	0.56	0.020	6.7
1992	1,346	212	0.35	0.020	2,450	368	0.63	0.02	92	28	0.02	0.006	3,888	572	10.4	2,542	369	0.65	0.021	6.8
1993	1,063	170	0.26	0.017	2,872	424	0.69	0.018	225	49	0.05	0.009	4,160	605	11.2	3,097	427	0.74	0.020	8.3
<u>T</u>																				
1986	---	---	---	---	412	37	---	---	42	5	---	---	---	---	---	454	37	---	---	2.9
1987	107	18	0.17	0.015	452	53	0.73	0.018	64	13	0.10	0.012	623	70	3.9	516	54	0.83	0.015	3.3
1988	73	12	0.16	0.017	350	34	0.75	0.020	42	9	0.09	0.013	465	43	2.9	392	35	0.84	0.017	2.5
1989	27	9	0.09	0.017	247	25	0.83	0.022	24	9	0.08	0.016	298	31	1.9	271	27	0.91	0.017	1.7
1990	46	12	0.13	0.018	286	37	0.82	0.020	15	7	0.04	0.011	347	42	2.2	301	38	0.87	0.018	1.9
1991	40	9	0.12	0.025	264	32	0.81	0.030	24	7	0.07	0.020	328	54	2.1	288	33	0.88	0.036	1.8
1992	74	15	0.10	0.017	665	66	0.85	0.020	42	11	0.05	0.013	782	75	4.9	707	67	0.90	0.023	4.5
1993	119	27	0.14	0.022	686	112	0.80	0.025	48	14	0.06	0.015	853	137	5.4	734	113	0.86	0.029	4.6
<u>East Twin</u>																				
1992	2,433	270	0.33	0.014	4,960	521	0.66	0.014	56	20	0.01	0.003	7,449	768	14.2	5,016	522	0.67	0.014	9.5
1993	1,304	182	0.22	0.013	4,668	588	0.76	0.014	98	28	0.02	0.004	6,070	757	11.5	4,766	589	0.78	0.015	9.1

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Appendix D. (Page 2 of 2).

Lake/ Year	Small (300-449 mm)				Medium (450-749 mm)				Large (Larger than 749 mm)				All (Larger than 299 mm)			All (Larger than 449 mm)			
	Abundance		Proportion		Abundance		Proportion		Abundance		Proportion		Abundance	Density		Abundance	Proportion	Density	
	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	(Fish/Ha)	Estimate	SE	Estimate	SE (Fish/Ha)
1990					1,246	141	0.97	0.014	37	11	0.03	0.014				1,283	145		1.3
1991	781	279	0.34	0.048	1,472	312	0.64	0.048	54	20	0.02	0.008	2,308	563	2.3	1,527	313	0.66	0.049
1992	1,372	242	0.48	0.034	1,430	159	0.50	0.037	66	19	0.02	0.006	2,868	353	2.9	1,496	160	0.52	0.038
1993	1,019	129	0.27	0.014	2,621	306	0.70	0.015	128	27	0.03	0.006	3,768	432	3.8	2,749	307	0.73	0.016

Harding

APPENDIX E

Appendix E. Number of northern pike marked and recaptured by event in Volkmar, T, and East Twin lakes, 1993.

Event	Fish Caught (C)	Newly Caught	Tags at Start of Daily Event (M)	Recaptured ^a (R)	Recapture Rate % (R/M)	Ratio (R/C) %
<u>T Lake:</u>						
1	31	31	0	0		
2	24	24	31	0	0.0	0.0
3	55	53	55	2	3.6	3.6
4	46	38	108	8	7.4	17.4
5	50	36	146	14	9.6	28.0
6	75	68	<u>182</u>	<u>7</u>	3.8	9.3
Total			250	31		
<u>East Twin Lake:</u>						
1	141	141	0	0		
2	260	255	141	5	3.5	1.9
3	215	203	396	12	3.0	5.6
4	189	171	599	18	3.0	9.5
5	189	164	<u>770</u>	<u>25</u>	3.2	13.2
Total			934	60		
<u>Volkmar Lake:</u>						
1	106	0	0	0		
2	88	84	106	4	3.8	4.5
3	117	112	190	5	2.6	4.3
4	96	84	302	12	4.0	12.5
5	138	127	386	11	2.8	8.0
6	71	63	513	8	1.6	11.3
7	73	70	<u>576</u>	<u>3</u>	0.5	4.1
Total			646	43		

^a Not necessarily unique fish.

Appendix F

Appendix F. Model selection criteria used by program CAPTURE for Volkmar, T, and East Twin lakes, 1993.

Model Lake Criteria ^a	M _o	M _h	M _b	M _{bh}	M _t	M _{th}	M _{tb}	M _{tbh}
Volkmar	0.15	0.00	0.22	0.13	<u>1.00</u>	0.74	0.68	0.32
T	0.48	0.39	0.02	0.00	<u>1.00</u>	0.66	0.46	0.69
East Twin	0.13	0.00	0.05	0.07	<u>1.00</u>	0.63	0.28	0.19

^a Model selected by CAPTURE has maximum value. Model selected by author is underlined, justification found in text.

APPENDIX G

Appendix G. Percent RSDs and abundance of northern pike (> 299 mm FL) in Volkmar, T, East Twin and Harding lakes, by year.

Lake	1986				1987				1988			
	RSD ^a	SE	Abundance	SE	RSD ^a	SE	Abundance	SE	RSD ^a	SE	Abundance	SE
<u>Volkmar</u>												
Stock	59	12.0	4,719	2,269	65	4.2	4,496	1,056	48	2.3	1,316	106
Quality	34	2.7	2,730	413	28	4.2	1,976	317	39	2.3	1,080	94
Preferred	7	0.8	562	91	6	0.9	412	64	12	1.6	352	49
Memorable	1	0.3	45	23	1	0.2	48	12	1	0.4	18	11
Trophy	0	---	---	---	0	---	---	---	0	---	---	---
Total	100		8,056	2,915	100		6,932	1,542	100		2,766	177
<u>T</u>												
Stock	14	1.6	---	---	40	2.9	248	33	37	3.0	173	21
Quality	44	2.4	---	---	27	2.6	166	25	35	2.9	161	20
Preferred	41	2.3	---	---	31	2.8	197	28	26	2.7	120	17
Memorable	1	0.5	---	---	2	0.8	11	5	2	0.9	10	4
Trophy	0	---	---	---	0	---	---	---	0	---	---	---
Total	100				100		623	70	100		465	43

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Appendix G. (Page 2 of 3).

Lake	1989				1990				1991			
	RSD ^a	SE	Abundance	SE	RSD ^a	SE	Abundance	SE	RSD ^a	SE	Abundance	SE
<u>Volkmar</u>												
Stock	36	1.8	481	90	66	2.5	2,674	483	65	1.8	2,939	361
Quality	44	1.9	581	107	25	2.3	1,026	203	25	1.6	1,141	155
Preferred	19	1.5	247	49	8	1.4	327	81	8	1.0	350	61
Memorable	2	0.5	21	7	< 1	0.3	11	11	2	0.5	80	24
Trophy	0	---	---	---	0	---	---	---	0	---	---	---
Total	100		1,330	285	100		4,038		100		4,510	541
<u>I</u>												
Stock	30	4.9	88	17	30	4.3	103	19	27	3.4	89	15
Quality	53	5.3	159	23	50	4.7	174	27	49	3.8	160	23
Preferred	16	3.9	47	13	20	3.8	70	16	23	3.2	75	13
Memorable	1	1.3	3	3	0	---	---	---	1	0.8	4	3
Trophy	0	---	---	---	0	---	---	---	0	---	---	---
Total	100		298	32	100		347	42	100		328	54
<u>Harding</u>												
Stock					18	3	230	45	57	7	1,305	458
Quality					64	4	816	102	34	6	787	152
Preferred					18	3	237	45	9	2	205	52
Memorable									<1	<1	11	8
Trophy												
Total					100		1,283		100		2,308	

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Appendix G. (Page 3 of 3).

Lake	1992				1993			
	RSD ^a	SE	Abundance	SE	RSD ^a	SE	Abundance	SE
<u>Volkmar</u>								
Stock	62	2.0	2,424	365	45	2.0	1,855	281
Quality	32	1.9	1,241	197	43	2.0	1,784	272
Preferred	5	0.9	197	45	10	1.2	450	83
Memorable	< 1	0.3	26	14	2	0.5	71	23
Trophy	0	---	---	---				
Total	100		3,888	572	100		4,160	605
<u>T</u>								
Stock	34	2.7	263	33	29	2.9	249	47
Quality	49	2.8	382	43	54	3.2	461	79
Preferred	16	2.1	132	21	16	2.3	136	29
Memorable	< 1	0.4	5	4	1	0.6	7	5
Trophy	0	---	---	---				
Total	100		782	75	100		853	137
<u>East Twin</u>								
Stock	65	1.4	4,847	510	53	1.6	3,227	414
Quality	31	1.3	2,358	263	42	1.6	2,569	335
Preferred	3	0.5	238	45	4	0.6	241	49
Memorable	0	---	---	---	<1	0.2	20	11
Trophy	< 1	0.1	6	6	<1	0.2	13	9
Total	100		7,449	768	100		6,070	757
<u>Harding</u>								
Stock	60	4	1,717	296	51	0.2	1,914	228
Quality	29	3	831	101	36	0.2	1,358	166
Preferred	11	2	314	50	13	0.1	487	69
Memorable	<1	<1	5	5	<1	0.1	8	6
Trophy					0			
Total	100		2,867		100		3,768	432

^a Stock = 300-524 mm, quality = 525-654 mm, preferred = 655-899 mm, memorable = 860-1,079 mm, and trophy = 1,080 mm and larger (Clark 1988).

^b Abundance unavailable; RSD's reflect sampled fish only.

APPENDIX H

Appendix H. Length frequencies of all northern pike sampled in Volkmar Lake, 1985-1993.

Length Class (mm)	1985		1986		1987		1988	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
< - 249	66	5.3	5	0.3	6	0.5	6	1.2
250 - 274	7	0.6	20	1.2	42	3.8	1	0.2
275 - 299	13	1.0	67	4.1	82	7.4	5	1.0
300 - 324	13	1.0	57	3.5	65	5.8	11	2.2
325 - 349	15	1.2	49	3.0	61	5.5	16	3.3
350 - 374	24	1.9	40	2.4	63	5.7	18	3.7
375 - 399	14	1.1	49	3.0	58	5.2	23	4.7
400 - 424	24	1.9	58	3.5	52	4.7	13	2.7
425 - 449	32	2.6	76	4.6	36	3.2	21	4.3
450 - 474	43	3.4	63	3.8	60	5.4	33	6.7
475 - 499	69	5.5	61	3.7	64	5.8	45	9.2
500 - 524	91	7.3	89	5.4	72	6.5	48	9.8
525 - 549	114	9.1	112	6.8	60	5.4	56	11.4
550 - 574	163	13.0	178	10.8	64	5.8	38	7.8
575 - 599	134	10.7	237	14.4	78	7.0	40	8.2
600 - 624	105	8.4	187	11.3	69	6.2	30	6.1
625 - 649	48	3.8	94	5.7	48	4.3	16	3.3
650 - 674	40	3.2	76	4.6	34	3.1	28	5.7
675 - 699	32	2.6	33	2.0	32	2.9	8	1.6
700 - 724	37	3.0	24	1.5	29	2.6	15	3.1
725 - 749	29	2.3	23	1.4	15	1.3	8	1.6
750 - 774	19	1.5	8	0.5	5	0.4	3	0.6
775 - 799	18	1.4	7	0.4	3	0.3	4	0.8
800 - 824	19	1.5	8	0.5	2	0.2	1	0.2
825 - 849	26	2.1	6	0.4	3	0.3	0	0.0
850 - 874	27	2.2	4	0.2	3	0.3	0	0.0
875 - 899	12	1.0	6	0.4	0	0.0	0	0.0
900 - 924	10	0.8	7	0.4	1	0.1	0	0.0
925 - 949	3	0.2	2	0.1	1	0.1	1	0.2
950 - 974	4	0.3	1	0.1	1	0.1	2	0.4
975 - 999	1	0.1	0	0.0	0	0.0	0	0.0
1,000 - 1,024	0	0.0	2	0.1	0	0.0	0	0.0
> 1,024	0	0.0	0	0.0	4	0.4	0	0.0
Total	1,252	100.0	1,649	100.0	1,113	100.0	490	100.0

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Appendix H. (Page 2 of 3).

Length Class (mm)	1989		1990		1991		1992	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
< - 249	7	1.0	7	2.0	0	0	0	0.0
250 - 274	6	0.8	22	6.2	2	0.2	0	0.0
275 - 299	8	1.1	41	11.6	2	0.2	0	0.0
300 - 324	16	2.2	50	14.1	89	8.8	23	3.9
325 - 349	14	2.0	56	15.8	75	7.4	31	5.2
350 - 374	16	2.2	40	11.3	77	7.6	29	4.9
375 - 399	13	1.8	20	5.6	102	10.1	42	7.1
400 - 424	15	2.1	30	8.5	94	9.3	33	5.6
425 - 449	37	5.2	12	3.4	55	5.5	47	7.9
450 - 474	40	5.6	10	2.8	60	5.9	56	9.5
475 - 499	53	7.4	12	3.4	60	5.9	57	9.6
500 - 524	47	6.6	11	3.1	66	6.5	51	8.6
525 - 549	70	9.8	3	0.8	43	4.3	57	9.6
550 - 574	83	11.7	6	1.7	55	5.5	46	7.8
575 - 599	73	10.3	11	3.1	50	5.0	44	7.4
600 - 624	38	5.3	11	3.1	45	4.5	32	5.4
625 - 649	30	4.2	6	1.7	34	3.4	9	1.5
650 - 674	22	3.1	0	0.0	16	1.6	7	1.2
675 - 699	15	2.1	1	0.3	14	1.4	8	1.4
700 - 724	25	3.5	0	0.0	9	0.9	5	0.8
725 - 749	11	1.5	1	0.3	11	1.1	1	0.2
750 - 774	13	1.8	0	0.0	8	0.8	4	0.7
775 - 799	22	3.1	1	0.3	8	0.8	0	0.0
800 - 824	17	2.4	1	0.3	9	0.9	3	0.5
825 - 849	5	0.7	0	0.0	3	0.3	2	0.3
850 - 874	10	1.4	1	0.3	10	1.0	1	0.2
875 - 899	2	0.3	0	0.0	5	0.5	2	0.3
900 - 924	0	0.0	0	0.0	2	0.2	1	0.2
925 - 949	2	0.3	1	0.3	3	0.3	1	0.2
950 - 974	0	0.0	0	0.0	1	0.1	0	0.0
975 - 999	2	0.3	0	0.0	1	0.1	0	0.0
1,000 - 1,024	0	0.0	0	0.0	0	0.0	0	0.0
> 1,024	0	0.0	0	0.0	0	0.0	0	0.0
Total	712	100.0	354	100.0	1,009	100.0	592	100.0

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Appendix H. (Page 3 of 3).

Length Class (mm)	1993	
	Number	Percent
< - 249		
250 - 274		
275 - 299		
300 - 324	18	2.8
325 - 349	30	4.6
350 - 374	34	5.3
375 - 399	26	4.0
400 - 424	30	4.6
425 - 449	27	4.2
450 - 474	24	3.7
475 - 499	46	7.1
500 - 524	53	8.2
525 - 549	49	7.6
550 - 574	81	12.5
575 - 599	62	9.6
600 - 624	53	8.2
625 - 649	28	4.3
650 - 674	17	2.6
675 - 699	10	1.5
700 - 724	10	1.5
725 - 749	13	2.0
750 - 774	8	1.2
775 - 799	8	1.2
800 - 824	5	0.8
825 - 849	3	0.5
850 - 874	1	0.2
875 - 899	1	0.2
900 - 924	1	0.2
925 - 949	4	0.6
950 - 974	2	0.3
975 - 999	1	0.2
1,000 - 1,024	1	0.2
> 1,024	0	0.0
Total		

APPENDIX I

Appendix I. Estimated age composition and cohort abundance of the northern pike population (> 299 mm FL) in Volkmar lake, 1985-1993.

Age	1985 ^a				1986				1987				1988			
	No. of Fish	Estimated			No. of Fish	Estimated			No. of Fish	Estimated			No. of Fish	Estimated		
		Proportion	Abundance	SE		Proportion	Abundance	SE		Proportion	Abundance	SE		Proportion	Abundance	SE
2	--	----	----	---	2	0.04	384	307	45	0.04	319	87	2	<0.01	13	9
3	--	----	----	---	11	0.26	2,110	1,244	213	0.22	1,500	359	27	0.06	175	34
4	--	----	----	---	11	0.17	1,394	738	242	0.24	1,648	374	75	0.18	486	60
5	90	0.31	1,238	137	23	0.16	1,262	316	278	0.23	1,611	284	124	0.29	804	80
6	59	0.21	840	112	19	0.11	924	231	215	0.15	1,021	152	118	0.28	764	77
7	49	0.17	677	99	14	0.10	824	267	95	0.06	439	73	50	0.11	324	48
8	42	0.13	525	86	11	0.07	535	169	47	0.03	176	33	18	0.04	117	28
9	47	0.09	377	65	5	0.03	243	111	35	0.02	115	24	5	0.01	32	15
10	36	0.05	179	35	7	0.04	282	107	17	0.01	51	14	7	0.02	45	17
11	26	0.03	120	27	1	0.01	49	49	16	0.01	42	12	---	---	---	---
12>	14	0.02	64	11	1	0.01	49	49	9	0.01	10	5	1	<0.01	6	6
Total	363	1.00	4,020	250	105	1.00	8,056	2,915	1,207	1.00	6,932	1,542	427	1.00	2,766	177

^a Includes fish > 449 mm only.

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Appendix I. (Page 2 of 2).

Age	1989				1990				1991				1993			
	No. of Fish	Estimated			No. of Fish	Estimated			No. of Fish	Estimated			No. of Fish	Estimated		
		Proportion	Abundance	SE		Proportion	Abundance	SE		Proportion	Abundance	SE		Proportion	Abundance	SE
2	25	0.04	51	14	35	0.10	411	97	22	0.04	170	41	2	0.004	16	12
3	28	0.04	58	15	99	0.29	1,162	227	185	0.32	1,428	192	72	0.141	585	106
4	68	0.11	140	30	51	0.15	599	130	130	0.22	1,003	143	82	0.160	666	118
5	128	0.20	263	52	51	0.15	599	130	62	0.10	479	81	109	0.213	886	149
6	172	0.27	354	68	53	0.15	622	135	80	0.14	618	98	95	0.186	772	133
7	108	0.17	222	44	31	0.09	364	89	48	0.08	371	68	42	0.082	341	70
8	64	0.10	132	28	15	0.04	176	54	34	0.06	263	54	50	0.098	406	80
9	25	0.04	51	14	6	0.02	70	31	14	0.02	108	31	30	0.059	244	56
10	12	0.02	25	8	2	0.01	23	17	5	<0.01	39	18	15	0.029	122	35
11	5	0.01	10	5	1	< 0.01	12	12	4	<0.01	31	16	7	0.014	57	23
12>	12	0.02	24	7	0	---	---	---	---	---	---	---	8	0.016	65	23.9
Total	647	1.00	1,330	240	344	1.00	4,038	354	584	1.00	4,510	541	584	1.00	4,160	

APPENDIX J

Appendix J. Estimated length-at-age of northern pike (> 299 mm FL) in Volkmar Lake, 1985-1993.

Age	1985				1986				1987				1988			
	No. of Fish	Fork Length		SE	No. of Fish	Fork Length		SE	No. of Fish	Fork Length		SE	No. of Fish	Fork Length		SE
		(mm)				(mm)				(mm)				(mm)		
<u>Males:</u>																
2	10	288	9	1	280	---	10	289	7	1	331	6				
3	23	350	10	4	351	25	125	323	5	1	309	12				
4	56	472	8	8	397	28	85	414	11	2	386	8				
5	48	538	5	7	542	16	127	503	8	5	508	7				
6	21	565	10	9	555	11	67	558	12	4	586	7				
7	21	565	9	4	597	18	28	576	10	---	---	---				
8	20	591	10	3	562	8	18	613	19	1	558	42				
9	21	665	14	5	618	32	11	612	26	---	---	---				
10	6	731	12	2	713	5	3	645	53	1	659	---				
11	6	706	15	---	---	---	1	741		---	---	---				
12>	2	728	17	1	743	---	1	751	---	---	---	---				
Total	234			44			476			15						
<u>Females:</u>																
2	6	301	7	---	---	---	8	293	9	---	---	---				
3	5	361	12	7	295	8	67	364	9	---	---	---				
4	22	503	7	13	550	20	118	458	8	---	---	---				
5	39	549	5	16	558	14	148	553	7	6	559	39				
6	36	582	7	9	593	19	140	609	7	5	633	35				
7	26	607	8	9	548	70	60	631	10	7	687	23				
8	22	669	9	6	648	16	28	667	10	1	667	---				
9	26	759	11	---	---	---	24	775	22	---	---	---				
10	30	806	11	5	838	33	13	781	31	---	---	---				
11	19	856	10	1	727	---	14	847	30	---	---	---				
12>	12	833	31	---	---	---	3	963	38	---	---	---				
Total	243			56			643			19						
<u>All Fish:</u>																
2	16	293	7	2	292	12	45	289	6	2	318	13				
3	28	352	12	11	315	13	213	337	4	27	362	12				
4	78	481	7	11	439	30	242	430	6	75	443	8				
5	87	543	5	23	553	11	278	524	5	124	512	8				
6	57	576	7	19	578	11	215	596	5	118	565	8				
7	47	588	8	14	556	45	95	607	9	50	619	13				
8	42	632	9	11	617	15	47	643	10	18	642	23				
9	47	717	11	5	618	32	35	704	24	5	627	25				
10	36	793	11	7	802	32	17	729	28	7	737	38				
11	25	820	10	1	727	---	16	805	63	---	---	---				
12>	14	817	47	1	743	---	4	983	81	1	972	---				
Total	477			105			1,207			427						

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Appendix J. (Page 2 of 2).

Age	1989			1990			1991			1993		
	Fork Length			Fork Length			Fork Length			Fork Length		
	No. of Fish	Mean (mm)	SE	No. of Fish	Mean (mm)	SE	No. of Fish	Mean (mm)	SE	No. of Fish	Mean (mm)	SE
<u>Males:</u>												
2	28	321	3	5	314	6	18	322	5	2	311	8
3	82	364	5	33	349	6	127	359	4	72	364	5
4	78	414	6	24	370	7	57	412	7	82	445	8
5	80	492	6	10	457	13	21	477	16	109	522	6
6	72	532	6	9	498	19	20	532	18	95	571	6
7	37	557	11	2	453	16	10	561	10	42	585	7
8	14	619	32	1	637	---	8	573	21	50	621	11
9	4	635	88	---	---	---	4	605	48	30	686	17
10	1	756	---	---	---	---	2	599	42	15	723	37
11	---	---	---	---	---	---	---	---	---	7	757	48
12>	2	818	45	---	---	---	---	---	---	8	894	43
Total	398			84			267					
<u>Females:</u>												
2	9	326	7	---	---	---	---	---	---	23	308	5
3	9	438	25	---	---	---	14	434	17	102	375	7
4	32	438	24	---	---	---	16	478	13	211	462	6
5	83	538	7	1	538	16	12	524	14	305	547	4
6	135	579	7	2	539	17	18	589	11	345	593	4
7	85	622	9	1	640	37	18	651	20	206	624	6
8	59	703	12	---	---	---	15	691	28	131	685	7
9	23	770	13	---	---	---	6	859	23	79	774	9
10	12	783	29	---	---	---	2	849	78	62	800	11
11	5	796	47	---	---	---	2	961	31	41	847	13
12>	13	841	21	3	870	14	2	828	48	33	851	15
Total	465			7			105			1,538		
<u>All Fish:</u>												
2	79	318	2	19	315	2	39	325	3	202	310	2
3	232	362	3	105	355	3	281	369	3	897	356	2
4	185	417	5	64	405	5	194	434	5	849	432	3
5	207	511	5	28	497	8	89	491	8	836	517	3
6	256	559	5	30	552	8	102	565	7	797	572	3
7	157	602	7	17	600	13	71	611	10	451	603	4
8	84	682	11	5	646	21	51	643	14	258	652	5
9	35	723	19	4	643	34	26	721	23	157	708	9
10	15	786	23	1	743	72	13	808	24	96	778	9
11	6	767	48	---	---	---	7	814	65	55	807	21
12>	15	838	13	3	870	14	6	804	32	44	842	18
Total	1,271			620			879			4,642		

APPENDIX K

Appendix K. Length frequencies of all northern pike sampled in T Lake, 1986-1993.

Length Class (mm)	1986						1987					
	Males		Females		All Fish		Males		Females		All Fish	
	No. of Fish	Percent	No. of Fish	Percent	No. of Fish	Percent	No. of Fish	Percent	No. of Fish	Percent	No. of Fish	Percent
< 249	0	0.0	0	0.0	1	0.3	0	0.0	0	0.0	6	1.9
250 - 274	0	0.0	0	0.0	1	0.3	0	0.0	0	0.0	0	0.0
275 - 299	0	0.0	0	0.0	2	0.5	0	0.0	0	0.0	0	0.0
300 - 324	1	0.7	0	0.0	3	0.8	4	4.3	0	0.0	10	3.2
325 - 349	4	3.0	0	0.0	6	1.6	7	7.6	4	2.4	12	3.8
350 - 374	2	1.5	0	0.0	4	1.0	4	4.3	0	0.0	7	2.2
375 - 399	1	0.7	0	0.0	3	0.8	2	2.2	1	0.6	4	1.3
400 - 424	6	4.4	0	0.0	7	1.8	5	5.4	1	0.6	8	2.6
425 - 449	5	3.7	2	1.2	9	2.4	2	2.2	4	2.4	8	2.6
450 - 474	4	3.0	0	0.0	6	1.6	8	8.7	5	3.0	15	4.8
475 - 499	3	2.2	3	1.7	11	2.9	16	17.4	7	4.1	25	8.0
500 - 524	5	3.7	3	1.7	10	2.6	12	13.0	8	4.7	21	6.7
525 - 549	9	6.7	4	2.3	17	4.5	7	7.6	6	3.6	16	5.1
550 - 574	12	8.9	7	4.1	21	5.5	3	3.3	7	4.1	12	3.8
575 - 599	16	11.9	12	7.0	28	7.3	6	6.5	9	5.3	19	6.1
600 - 624	22	16.3	12	7.0	40	10.5	7	7.6	6	3.6	13	4.2
625 - 649	21	15.6	11	6.4	43	11.3	3	3.3	10	5.9	15	4.8
650 - 674	15	11.1	24	14.0	42	11.0	2	2.2	14	8.3	17	5.4
675 - 699	3	2.2	20	11.6	26	6.8	1	1.1	19	11.2	24	7.7
700 - 724	3	2.2	16	9.3	24	6.3	3	3.3	15	8.9	21	6.7
725 - 749	3	2.2	20	11.6	30	7.9	0	0.0	15	8.9	16	5.1
750 - 774	0	0.0	13	7.6	17	4.5	0	0.0	9	5.3	10	3.2
775 - 799	0	0.0	9	5.2	11	2.9	0	0.0	5	3.0	7	2.2
800 - 824	0	0.0	4	2.3	7	1.8	0	0.0	10	5.9	11	3.5
825 - 849	0	0.0	5	2.9	5	1.3	0	0.0	4	2.4	5	1.6
850 - 874	0	0.0	2	1.2	2	0.5	0	0.0	3	1.8	4	1.3
875 - 899	0	0.0	3	1.7	3	0.8	0	0.0	3	1.8	3	1.0
900 - 924	0	0.0	1	1.6	1	0.3	0	0.0	1	0.6	1	0.3
925 - 949	0	0.0	0	0.0	0	0.0	0	0.0	2	1.2	2	0.6
950 - 974	0	0.0	0	0.0	0	0.0	0	0.0	1	0.6	1	0.3
975 - 999	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
1,000-1,024	0	0.0	1	0.6	1	0.3	0	0.0	0	0.0	0	0.0
> 1,024	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	135	100.0	172	100.0	381	100.0	92	100.0	169	100.0	313	100.0

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Appendix K. (Page 2 of 4).

Length Class (mm)	1988						1989					
	Males		Females		All Fish		Males		Females		All Fish	
	No. of Fish	Percent	No. of Fish	Percent	No. of Fish	Percent	No. of Fish	Percent	No. of Fish	Percent	No. of Fish	Percent
< 249	0	0.0	0	0.0	45	15.1	0	0.0	0	0.0	0	0.0
250 - 274	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
275 - 299	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
300 - 324	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
325 - 349	6	4.7	0	0.0	7	2.3	0	0.0	0	0.0	3	3.3
350 - 374	8	6.2	0	0.0	8	2.7	2	5.4	0	0.0	3	3.3
375 - 399	5	3.9	0	0.0	5	1.7	0	0.0	0	0.0	1	1.1
400 - 424	3	2.3	0	0.0	4	1.3	0	0.0	0	0.0	1	1.1
425 - 449	5	3.9	2	1.8	7	2.3	0	0.0	0	0.0	0	0.0
450 - 474	8	6.2	2	1.8	12	4.0	0	0.0	0	0.0	1	1.1
475 - 499	8	6.2	4	3.5	13	4.3	2	5.4	0	0.0	4	4.4
500 - 524	14	10.9	1	0.9	16	5.4	2	5.4	0	0.0	5	5.6
525 - 549	16	12.4	6	5.3	22	7.4	4	10.8	4	14.3	10	11.1
550 - 574	17	13.2	6	5.3	23	7.7	6	16.2	0	0.0	12	13.3
575 - 599	8	6.2	12	10.6	22	7.4	2	5.4	2	7.1	6	6.7
600 - 624	9	7.0	7	6.2	16	5.4	4	10.8	4	14.3	9	10.0
625 - 649	6	4.7	9	8.0	16	5.4	9	24.3	0	0.0	10	11.1
650 - 674	6	4.7	6	5.3	13	4.3	2	5.4	7	25.0	9	10.0
675 - 699	6	4.7	9	8.0	16	5.4	1	2.7	0	0.0	1	1.1
700 - 724	2	1.6	14	12.4	17	5.7	0	0.0	2	7.1	2	2.2
725 - 749	1	0.8	10	8.8	11	3.7	1	2.7	2	7.1	3	3.3
750 - 774	1	0.8	6	5.3	6	2.0	0	0.0	2	7.1	3	3.3
775 - 799	0	0.0	3	2.7	3	1.0	0	0.0	0	0.0	0	0.0
800 - 824	0	0.0	3	2.7	3	1.0	0	0.0	2	7.1	2	2.2
825 - 849	0	0.0	1	0.9	2	0.7	1	2.7	1	3.6	2	2.2
850 - 874	0	0.0	5	4.4	5	1.7	1	2.7	1	3.6	2	2.2
875 - 899	0	0.0	3	2.7	3	1.0	0	0.0	0	0.0	0	0.0
900 - 924	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
925 - 949	0	0.0	3	2.7	3	1.0	0	0.0	1	3.6	1	0.0
950 - 974	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	1.1
975 - 999	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
1,000-1,024	0	0.0	1	0.9	1	0.3	0	0.0	0	0.0	0	0.0
> 1,024	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	129	100.0	113	100.0	299	100.0	37	100.0	28	100.0	90	100.0

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Appendix K. (Page 3 of 4).

Length Class (mm)	1990						1991		1992	
	Males		Females		All Fish		All Fish		All Fish	
	No. of Fish	Percent	No. of Fish	Percent	No. of Fish	Percent	No. of Fish	Percent	No. of Fish	Percent
< 249	0	0.0	1	1.3	1	0.5	1	0.7	0	0.0
250 - 274	0	0.0	0	0.0	0	0.0	0	0	0	0.0
275 - 299	0	0.0	0	0.0	0	0.0	2	1.3	0	0.0
300 - 324	0	0.0	0	0.0	2	1.0	4	2.6	2	0.6
325 - 349	2	2.4	0	0.0	3	1.4	5	3.3	3	1.0
350 - 374	0	0.0	0	0.0	1	0.5	2	1.3	3	1.0
375 - 399	3	3.6	0	0.0	3	1.4	0	0	1	0.3
400 - 424	1	1.2	1	1.3	4	1.9	5	3.3	11	3.5
425 - 449	1	1.2	0	0.0	4	1.9	3	2.0	10	3.2
450 - 474	7	8.4	0	0.0	11	5.3	9	6.0	19	6.0
475 - 499	5	6.0	3	3.9	13	6.3	6	4.0	28	8.9
500 - 524	5	6.0	1	1.3	6	2.9	10	6.6	29	9.2
525 - 549	4	4.8	2	2.6	6	2.9	5	3.3	30	9.5
550 - 574	9	10.8	2	2.6	13	6.3	21	13.9	34	10.8
575 - 599	22	26.5	7	9.2	35	16.9	7	4.6	37	11.7
600 - 624	13	15.7	8	10.5	30	14.5	6	4.0	29	9.2
625 - 649	4	4.8	5	6.6	14	6.8	19	12.6	17	5.4
650 - 674	0	0.0	9	11.8	11	5.3	13	8.6	20	6.3
675 - 699	1	1.2	11	14.5	14	6.8	10	6.6	11	3.5
700 - 724	2	2.4	7	9.2	11	5.3	7	4.6	11	3.5
725 - 749	1	1.2	4	5.3	6	2.9	3	2.0	3	1.0
750 - 774	1	1.2	3	3.9	5	2.4	3	2.0	7	2.2
775 - 799	0	0.0	4	5.3	4	1.9	1	0.7	2	0.6
800 - 824	0	0.0	3	3.9	3	1.4	5	3.3	3	1.0
825 - 849	1	1.2	1	1.3	2	1.0	2	1.3	3	1.0
850 - 874	1	1.2	2	2.6	3	1.4	2	1.3	0	0.0
875 - 899	0	0.0	1	1.3	1	0.5	0	0.0	0	0.0
900 - 924	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
925 - 949	0	0.0	0	0.0	0	0.0	0	0.0	2	0.6
950 - 974	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
975 - 999	0	0.0	1	1.3	1	0.5	0	0.0	0	0.0
1,000-1,024	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
> 1,024	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	83	100.0	76	100.0	207	100.0	151	100.0	315	100.0

Appendix K. (Page 4 of 4).

Length Class (mm)	1993	
	All Fish	
	No. of Fish	Percent
< 249		
250 - 274		
275 - 299		
300 - 324	8	3.2
325 - 349	5	2.0
350 - 374	8	3.2
375 - 399	4	1.6
400 - 424	2	0.8
425 - 449	8	3.2
450 - 474	6	2.4
475 - 499	16	6.4
500 - 524	16	6.4
525 - 549	25	10.0
550 - 574	32	12.8
575 - 599	28	11.2
600 - 624	31	12.4
625 - 649	17	6.8
650 - 674	11	4.4
675 - 699	9	3.6
700 - 724	5	2.0
725 - 749	5	2.0
750 - 774	3	1.2
775 - 799	2	0.8
800 - 824	4	1.6
825 - 849	3	1.2
850 - 874	0	0.0
875 - 899	1	0.4
900 - 924	1	0.4
925 - 949	0	0.0
950 - 974	0	0.0
975 - 999	0	0.0
1,000-1,024	0	0.0
> 1,024	0	0.0
Total		

APPENDIX L

Appendix L. Estimated age composition and cohort abundance of the northern pike population (> 299 mm FL) in T Lake, 1986-1993.

Age	1986				1987				1988				1989			
	No. of Fish	^a Estimated			No. of Fish	Estimated			No. of Fish	Estimated			No. of Fish	Estimated		
		Proportion	Abundance	SE		Proportion	Abundance	SE		Proportion	Abundance	SE		Proportion	Abundance	SE
2	---	----	---	---	1	<.01	3	3	1	<.01	2	2	1	0.01	4	4
3	3	0.05	22	13	9	0.04	26	9	7	0.03	13	5	4	0.05	14	7
4	4	0.06	29	14	14	0.07	41	12	15	0.06	28	7	3	0.04	11	6
5	7	0.11	51	19	32	0.15	94	19	29	0.11	51	11	7	0.08	25	9
6	10	0.16	73	22	42	0.20	125	22	57	0.23	107	16	10	0.12	36	11
7	10	0.16	73	22	28	0.13	82	17	54	0.21	97	15	17	0.20	61	15
8	13	0.21	95	25	27	0.13	79	17	40	0.16	74	13	18	0.22	65	15
9	8	0.13	59	20	25	0.12	73	16	15	0.06	28	7	12	0.14	43	12
10	5	0.08	37	16	26	0.12	76	16	12	0.07	33	8	2	0.02	7	5
11	2	0.03	15	10	4	0.02	12	6	6	0.03	14	5	4	0.05	14	7
12	---	---	---	---	4	0.02	12	6	6	0.04	18	6	5	0.06	18	8
Total	62	1.00	454	37	212	1.00	623	70	242	1.00	465	43	83	1.00	298	31

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Appendix L. (Page 2 of 2).

Age	1990				1991				1993			
	No. of Fish	Estimated			No. of Fish	Estimated			No. of Fish	Estimated		
		Proportion	Abundance	SE		Proportion	Abundance	SE		Proportion	Abundance	SE
2	3	0.04	15	8	1	0.01	3	3	3	0.014	12	7
3	6	0.08	28	11	9	0.06	21	7	17	0.079	68	19
4	8	0.11	38	13	15	0.11	36	10	37	0.173	147	32
5	6	0.08	28	11	12	0.09	28	19	83	0.388	331	60
6	14	0.18	62	17	19	0.13	44	11	35	0.164	140	31
7	14	0.18	62	17	23	0.17	56	12	5	0.023	20	9
8	15	0.20	70	18	34	0.25	82	15	13	0.061	52	16
9	8	0.11	38	13	15	0.11	35	10	9	0.042	36	13
10	1	0.01	3	5	4	0.03	10	5	6	0.028	24	10
11	---	---	---	---	2	0.02	5	4	4	0.019	16	8
12>	1	0.01	3	5	3	0.02	8	5	1	0.005	4	4
Total	76	1.00	347	42	137	1.00	328	54	83	1.00	298	31

^a Includes fish > 449 mm only.

APPENDIX M

Appendix M. Estimated length-at-age of northern pike (> 299 mm FL) in T Lake, 1986-1993.

Age	1986			1987			1988			1989		
	Fork Length			Fork Length			Fork Length			Fork Length		
	No. of Fish	Mean (mm)	SE	No. of Fish	Mean (mm)	SE	No. of Fish	Mean (mm)	SE	No. of Fish	Mean (mm)	SE
<u>Males:</u>												
2	---	---	---	1	303	---	---	---	---	---	---	---
3	3	340	6	7	307	6	6	336	8	6	334	9
4	4	387	37	10	395	18	12	361	17	13	439	10
5	5	495	51	20	436	14	23	445	19	6	497	13
6	5	577	31	19	488	10	32	513	10	11	511	12
7	5	604	30	8	551	20	27	528	12	21	551	7
8	6	675	25	7	582	19	12	579	13	23	578	7
9	1	621	---	2	616	22	6	643	24	13	596	8
10	1	747	---	4	613	49	3	589	41	2	635	45
11	---	---	---	---	---	---	3	667	4	3	751	29
12>	---	---	---	---	---	---	1	820	---	3	807	5
Total	30			78			125			101		
<u>Females:</u>												
2	---	---	---	---	---	---	---	---	---	---	---	---
3	---	---	---	2	314	9	---	---	---	---	---	---
4	---	---	---	4	405	38	1	304	---	2	469	4
5	2	511	63	12	530	34	5	529	44	4	522	20
6	5	613	28	23	548	14	21	565	15	12	591	24
7	5	683	22	20	617	15	24	620	15	17	553	39
8	7	730	14	20	654	18	26	658	14	24	633	11
9	7	773	22	23	672	17	9	734	37	19	689	12
10	4	821	36	22	748	16	14	688	60	7	735	36
11	2	752	22	4	767	27	4	777	35	3	783	30
12>	---	---	---	8	862	34	9	837	31	5	835	20
Total	32			138			113			93		
<u>All Fish:</u>												
2	---	---	---	3	289	6	1	252	4	2	302	2
3	3	340	6	14	337	4	7	327	13	13	343	11
4	4	387	37	23	430	6	15	365	13	22	439	7
5	7	500	38	35	524	5	29	455	6	19	497	11
6	10	595	20	53	596	5	57	532	6	31	551	13
7	10	643	22	36	607	9	54	573	9	48	550	14
8	13	706	15	35	643	10	40	632	15	59	604	7
9	8	751	28	31	704	24	15	698	29	35	653	11
10	5	806	31	27	729	28	17	672	29	9	713	32
11	2	752	22	6	805	63	7	730	60	6	767	20
12>	---	---	---	4	842	86	10	821	28	8	824	18
Total	62			267			252			252		

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Appendix M. (Page 2 of 2).

Age	1990			1991			1993		
	No. of Fish	Fork Length		No. of Fish	Fork Length		No. of Fish	Fork Length	
		(mm)			(mm)			(mm)	
		Mean	SE		Mean	SE		Mean	SE
<u>Males:</u>									
2	---	---	---	---	---	---			
3	3	340	1	4	332	14			
4	4	430	1	9	437	14			
5	3	474	---	5	496	16			
6	5	509	1	7	509	12			
7	6	553	---	8	552	7			
8	4	564	1	14	580	9			
9	2	590	---	3	595	10			
10	---	---	---	---	---	---			
11	---	---	---	1	720	---			
12>	---	---	---	2	787	---			
Total	27			53					
<u>Females:</u>									
2	---	---	---	---	---	---			
3	---	---	---	---	---	---			
4	1	465	---	2	468	4			
5	1	559	---	4	522	20			
6	5	540	17	8	594	34			
7	6	609	25	11	537	59			
8	7	630	22	13	638	14			
9	5	694	26	11	683	18			
10	1	663	---	4	761	41			
11	---	---	---	1	834	---			
12>	1	826	---	1	826	---			
Total	27			55					
<u>All Fish:</u>									
2	3	281	14	1	300	---	3	308	56
3	9	350	15	9	350	16	17	350	4
4	19	441	7	15	441	9	37	490	37
5	12	496	11	12	496	11	83	556	6
6	21	561	17	19	555	18	35	597	8
7	31	558	21	23	551	28	5	643	14
8	41	606	8	34	608	9	13	707	12
9	23	662	14	15	668	17	9	698	35
10	7	732	36	4	761	41	6	785	29
11	2	777	57	2	777	57	4	803	31
12>	3	800	---	3	800	---	1	740	--
Total	171			137					

APPENDIX N

Appendix N. Estimated age composition and cohort abundance of the northern pike populations (> 299 mm FL) in East Twin Lake, 1992 and 1993.

Age	No. of Fish	Proportion	SE	Abundance	SE
<u>1992</u>					
2	2	0.002	0.001	13	10
3	89	0.080	0.008	597	86
4	239	0.215	0.012	1,604	189
5	346	0.312	0.014	2,322	261
6	210	0.189	0.012	1,409	169
7	94	0.085	0.008	631	90
8	63	0.057	0.007	423	67
9	37	0.033	0.005	248	47
10	23	0.021	0.004	154	35
11	2	0.002	0.001	13	10
12	3	0.003	0.002	20	12
13	1	0.001	0.001	7	7
18	1	0.001	0.001	7	7
Total	1,110	100		7,449	768
<u>1993</u>					
2	4	0.006	0.003	38	19
3	57	0.089	0.011	537	95
4	138	0.214	0.016	1,301	189
5	190	0.295	0.018	1,791	248
6	114	0.177	0.015	1,075	162
7	68	0.106	0.012	641	108
8	46	0.071	0.010	434	82
9	12	0.019	0.005	113	35
10	11	0.017	0.005	104	33
13	1	0.002	0.002	9	9
14	1	0.002	0.002	9	9
15	1	0.002	0.002	9	9
19	1	0.002	0.002	9	9
Total	644	100		6,070	757

APPENDIX O

Appendix O. Estimated length-at-age of northern pike (> 299 mm FL) in East Twin Lake, 1992 and 1993.

Number of Fish	Age	Mean Length (mm)	SE
<u>1992</u>			
78 ^a	---	511	10
2	2	320	< 1
89	3	381	4
239	4	428	3
346	5	487	3
210	6	519	4
94	7	564	6
63	8	606	6
37	9	632	11
23	10	616	15
2	11	729	49
3	12	706	72
1	13	785	—
1	18	1,140	—
<hr/>			
Total	1,188		
<hr/>			
<u>1993</u>			
287 ^a	---	521	5
4	2	316	7
57	3	363	5
138	4	453	4
190	5	514	3
114	6	559	4
68	7	596	5
46	8	620	8
12	9	637	22
11	10	756	32
1	13	1,100	---
1	14	930	---
1	15	1,100	—
1	19	610	—
<hr/>			
Total	931		

^a Includes northern pike for which age was not determined due to unreadable scales being taken.

APPENDIX P

Appendix P. Length frequency of all northern pike sampled in East Twin Lake, 1993.

Length Class (mm)	No. of Fish	Percent
<u>1992:</u>		
300 - 324	11	0.9
325 - 349	10	0.8
350 - 374	60	5.1
375 - 399	66	5.6
400 - 424	111	9.3
425 - 449	130	10.9
450 - 474	135	11.4
475 - 499	128	10.8
500 - 524	122	10.3
525 - 549	100	8.4
550 - 574	82	6.9
575 - 599	86	7.2
600 - 624	82	6.9
625 - 649	23	1.9
650 - 674	15	1.3
675 - 699	8	0.7
700 - 724	5	0.4
725 - 774	5	0.4
775 - 799	4	0.3
800 - 824	1	0.1
825 - 1124	1	0.1
1125 -	1	0.1
Total	1,188	100

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Appendix P. (Page 2 of 2).

Length Class (mm)	No. of Fish	Percent
<u>1993:</u>		
300 - 324	14	1.5
325 - 349	35	3.8
350 - 374	17	1.8
375 - 399	22	2.4
400 - 424	37	4.0
425 - 449	75	8.1
450 - 474	88	9.5
475 - 499	107	11.5
500 - 524	100	10.7
525 - 549	69	7.4
550 - 574	84	9.0
575 - 599	110	11.8
600 - 624	89	9.6
625 - 649	35	3.8
650 - 674	18	1.9
675 - 699	11	1.2
700 - 724	2	0.2
725 - 749	3	0.3
750 - 774	1	0.1
775 - 799	4	0.4
800 - 824	2	0.2
825 - 849	3	0.3
850 - 924	2	0.2
925 -1099	1	0.1
1100 -	2	0.2
Total	931	

APPENDIX Q

Appendix Q. Estimated proportion of the population, cohort abundance, and mean length by age class for northern pike in Harding Lake, 1990-1993.

Age	Sample Size	Proportion		Abundance		Mean Length	
		P	(SE)	N	(SE)	L	(SE)
<u>1990^a</u>							
2	1	0.01	(0.005)	11	(11)	305	
3	15	0.07	(0.018)	160	(48)	330	(8)
4	47	0.21	(0.029)	484	(106)	407	(6)
5	88	0.29	(0.030)	657	(125)	487	(5)
6	149	0.26	(0.026)	594	(86)	536	(3)
7	112	0.11	(0.010)	242	(26)	594	(3)
8	43	0.04	(0.006)	93	(15)	668	(6)
9	16	0.02	(0.004)	35	(9)	700	(14)
10	4	<0.01	(0.002)	9	(4)	831	(9)
<u>1991^b</u>							
3	11	0.054	(0.017)	126	(56)	321	(8)
4	15	0.074	(0.020)	171	(72)	375	(10)
5	30	0.149	(0.030)	343	(131)	394	(6)
6	27	0.130	(0.027)	299	(111)	473	(11)
7	29	0.129	(0.024)	299	(101)	511	(15)
8	58	0.208	(0.031)	481	(109)	571	(9)
9	29	0.101	(0.022)	234	(60)	560	(31)
10	36	0.116	(0.028)	267	(63)	619	(22)
11	6	0.018	(0.007)	41	(18)	657	(38)
12	7	0.021	(0.008)	47	(20)	791	(40)
<u>1992^b</u>							
3	51	0.19	(0.025)	538	(111)	352	(7)
4	87	0.31	(0.031)	892	(164)	422	(7)
5	75	0.21	(0.023)	609	(97)	533	(9)
6	44	0.11	(0.017)	307	(55)	601	(12)
7	45	0.09	(0.017)	268	(47)	652	(10)
8	19	0.04	(0.010)	112	(28)	651	(13)
9	20	0.04	(0.009)	113	(27)	698	(16)
10	4	0.01	(0.004)	23	(11)	779	(35)
11	1	<0.01	(0.002)	6	(6)	769	

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Appendix Q. (Page 2 of 2).

Age	Sample Size	Proportion		Abundance		Mean Length	
		P	(SE)	N	(SE)	L	(SE)
<u>1993</u>							
2	16	0.019	(0.005)	71	(19)	333	(5)
3	128	0.152	(0.012)	571	(80)	383	(4)
4	254	0.301	(0.016)	1,134	(143)	481	(4)
5	220	0.261	(0.015)	982	(126)	555	(5)
6	86	0.102	(0.010)	384	(59)	600	(8)
7	71	0.084	(0.010)	317	(51)	656	(8)
8	46	0.055	(0.008)	205	(38)	666	(10)
9	18	0.021	(0.005)	80	(21)	740	(19)
10	3	0.004	(0.004)	13	(8)	783	(63)
12	1	0.001	(0.001)	4	(4)	677	
13	1	0.001	(0.001)	4	(4)	660	

^a Estimates were made using inter-seasonal data sets from 1990 and 1991. Sample sizes were from 1990.

^b Estimates were made using intra-seasonal data sets from 1991 and 1992. Sample sizes were from Event 2 in 1991 and 1992.

